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Rola terenów zieleni we współczesnym mieście. W stronę miejskiej odporności

Rozprawa doktorska wykonana pod kierunkiem
promotora dr hab. inż. Krzysztofa Rogatki, prof. UMK
oraz
promotora pomocniczego dr hab. inż. Tomasza Noszczyka, prof. URK

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Tab. 1. Cytowania artykułów tworzących rozprawę doktorską

Artykuł	Data pierwszej publikacji online	Liczba cytowań		
		Web of Science	Scopus	Google Scholar
A1	04.04.2023 r.	-	4	4
A2	02.10.2024 r.	8	10	11
A3	15.03.2022 r.	5	4	5
A4	08.09.2026 r.	-	-	-

Źródło: opracowanie własne na podstawie Web of Science, Scopus i Google Scholar

**Ustawa z dnia 20 lipca 2018 r. Prawo o szkolnictwie wyższym i nauce, poz. 1668, art. 187, ust. 3., brzmienie: Rozprawę doktorską może stanowić praca pisemna, w tym monografia naukowa, zbiór opublikowanych i powiązanych tematycznie artykułów naukowych, praca projektowa, konstrukcyjna, technologiczna, wdrożeniowa lub artystyczna, a także samodzielna i wyodrębniona część pracy zbiorowej.*
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Na przyrodę nie można już więcej patrzeć jak na produkt wykorzystania, musi ona we wszystkich formach jej jawienia być doświadczana jako partner

Hans-Georg Gadamer

„Dziedzictwo Europy", przeł. A. Przyłębski, Warszawa 1992 r.

PODZIĘKOWANIA

Nauka jest pasją, która szybko uzależnia. Jest bardzo wymagająca, jednak przy współudziale i towarzystwie właściwych osób staje się życiem pełnym inspiracji i niespodzianek. W tym miejscu chciałbym podziękować osobom, które włożyły cenny wkład powstanie mojej rozprawy.

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Podziękowania kieruje również w stronę zespołu badaczy, z którymi miałem okazję współpracować w ramach przygotowania niniejszej rozprawy. Dziękuję za możliwość wymiany poglądów oraz spostrzeżeń dotyczących poruszanych w rozprawie tematów.

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1. Wprowadzenie

Współczesne miasta funkcjonują w warunkach polikryzysów, wśród których można wyróżnić m.in. narastającą presję środowiskową, problemy społeczne i konflikty przestrzenne. Wspomniane kryzysy wymuszają redefinicję dotychczasowych modeli rozwoju miast. W tym kontekście rośnie znaczenie m.in. terenów zieleni miejskiej, które przestają być postrzegane wyłącznie jako element estetyczny lub rekreacyjny. Tereny zieleni stają się obecnie ważnym komponentem systemu miejskiego i poprawiają jego funkcjonowanie (Pauleit i in., 2011; Hansen i in., 2017).

Badania nad zielenią miejską często koncentrowały się na jej klasycznych funkcjach, jak np. poprawia estetyki przestrzeni czy zapewnienie możliwości rekreacji (Egerer i in., 2024; Zhang i in., 2024). Tereny zieleni rozumiano jako uzupełnienie struktury urbanistycznej, a ich znaczenie wskazywano przede wszystkim w kontekście jakości życia mieszkańców (Chiesura, 2004) i ochrony środowiska (Jato-Espino i in., 2023). Współczesne wyzwania rozwojowe wskazują jednak, że takie podejście wymaga rozszerzenia o nowe perspektywy badawcze (Paudel i States, 2023; Sikorska i in., 2023; Son i in., 2026). Szczególne znaczenie zyskuje analiza roli terenów zieleni w kontekście narastających kryzysów oddziałujących na miasta. Kryzys klimatyczny, przejawiający się m.in. wzrostem temperatur, nasileniem fal upałów czy ulewnych, krótkotrwałych deszczy wymaga wdrażania środowiskowych rozwiązań, wśród których zieleń miejska odgrywa istotną rolę (Januchta-Szostak, 2020; Li i in., 2023). Jednocześnie miasta mierzą się z wyzwaniami demograficznymi, w tym starzeniem się społeczeństw (Van Hoof i in. 2018; Kazak, 2023). W tym kontekście zwiększa się znaczenie przestrzeni publicznych dedykowanych seniorom (Łukaszewicz i in.., 2023). Ponadto nasilające się procesy migracyjne oraz rosnąca różnorodność społeczna prowadzą do większego zróżnicowania potrzeb mieszkańców miast (Cheng i in., 2024). Rezultatem tego jest wzrost znaczenia przestrzeni sprzyjających integracji i budowaniu kapitału społecznego, które wzmacniają rezyliencję systemu miejskiego. Funkcję tę mogą pełnić tereny zieleni miejskiej, które będąc przestrzeniami ogólnodostępnymi umożliwiają interakcje społeczne i wzmacniają więzi lokalne (Jennings i in., 2024). Zwiększona intensywność życia miejskiego oraz towarzyszący jej stres środowiskowy prowadzą natomiast do pogorszenia dobrostanu psychicznego mieszkańców (Bock i in., 2026). Współczesne społeczeństwo coraz częściej zmaga się z problemami psychicznymi, takimi jak stres, depresja czy zaburzenia lękowe,

szczególnie w dużych miastach (Lederbogen i in., 2011). Szybkie tempo życia, hałas i ograniczony kontakt z naturą negatywnie wpływają na dobrostan mieszkańców (Peen i in., 2010). W tym kontekście istotną rolę odgrywają tereny zieleni miejskiej, które pomagają redukować stres i pozytywnie wspierają zdrowie psychiczne (Lopez-Haro i in., 2024). Badania pokazują również, że dostęp do terenów zieleni wiąże się z wyższą jakością życia i lepszym stanem psychicznym mieszkańców miast (White i in., 2013). W tej sytuacji kontakt z zielenią staje się istotnym czynnikiem łagodzącym negatywne skutki urbanizacji (Bratman i in., 2019). W obliczu powyższego konieczne jest odejście od tradycyjnego postrzegania zieleni jako elementu uzupełniającego przestrzeń na rzecz traktowania jej jako strategicznego zasobu wspierającego zdolność miast do adaptacji i transformacji. W odniesieniu do kryzysów pojawiających się w przestrzeniach miejskich szczególnego znaczenia nabiera odporność miejska (urban resilience). Koncepcja ta rozumiana jest jako zdolność systemu miejskiego do absorbowania zakłóceń, adaptacji do zmieniających się warunków oraz utrzymania kluczowych funkcji (Meerow i in., 2016).

Współcześnie tereny zieleni miejskiej pełnią coraz bardziej zróżnicowane funkcje związane z wyzwaniami klimatycznymi i społecznymi. Wykorzystywane są m.in. jako elementy systemów retencji wód opadowych, czego przykładem są ogrody deszczowe, niecki infiltracyjne oraz parki retencyjne ograniczające ryzyko podtopień (Czerniakowski i Gargała-Polar, 2020). Poprzez obniżanie temperatury i poprawę przewietrzania miasta, zieleń miejska odgrywa również istotną rolę w redukcji zjawiska miejskiej wyspy ciepła. Coraz większe znaczenie zyskują także zielone dachy i zielone ściany, które poprawiają izolację termiczną budynków oraz wspierają bioróżnorodność (Bowler i in., 2010; Berardi i in., 2014). Z kolei ogródki działkowe, ogrody społeczne, farmy miejskie i zielone przestrzenie terapeutyczne wspierają integrację społeczną, edukację ekologiczną oraz zdrowie psychiczne mieszkańców (Soga i in., 2017; Maćkiewicz i Asuero, 2021). Współczesne uwarunkowania rozwoju miast oraz dynamika zachodzących przemian przestrzennych i społecznych sprawiają, że zieleń miejska odgrywa złożoną i ważną rolę w kształtowaniu środowiska miejskiego, funkcjonowaniu jego użytkowników oraz budowaniu odporności.

******

Inspiracją do podjęcia badań nad rolą terenów zieleni miejskiej ze szczególnym uwzględnieniem ich wkładu w budowanie odporności miejskiej były osobiste

doświadczenia autora związane z pandemią COVID-19, która wprost uwidoczniła znaczenie codziennego dostępu do zieleni jako przestrzeni regeneracji i kontaktów społecznych. W tym kontekście szczególnie istotny był postulat Światowej Organizacji Zdrowia. Według WHO dostęp do terenów zieleni stanowi jeden z kluczowych czynników wspierających zdrowie fizyczne i psychiczne mieszkańców miast. Doświadczenia tego okresu pokazały, że zieleń miejska pełni funkcje wykraczające poza tradycyjne ujęcia, co stało się impulsem do podjęcia badań nad jej rolą w funkcjonowaniu współczesnych miast i budowania ich rezyliencji.

1.1. Aktualny stan wiedzy

W dobie postępującej urbanizacji współczesne miasta stają u progu wielu wyzwań, które permanentnie wpływają na ich strukturę oraz funkcje. Jak wskazuje Harvey (2015), miasta stają się miejscem kumulacji kryzysów społecznych, ekonomicznych i przestrzennych, a urbanizacja prowadzi do nowych form ich przeciążenia. Podobne stanowisko prezentują polscy badacze, wskazując na narastający chaos przestrzenny, konflikty funkcjonalne oraz rosnącą presję urbanizacyjną jako jedne z najważniejszych wyzwań współczesnych miast (Jałowiecki, 2005; Kowalewski i in., 2020; Markowski i Drzazga, 2024).

Szczególne znaczenie przypisuje się kryzysom środowiskowym i klimatycznym, których konsekwencją jest wzrost częstotliwości zjawisk ekstremalnych, takich jak fale upałów czy powodzie (Dodman i in., 2023). Równolegle obserwuje się podatność systemów miejskich na wahania gospodarcze, prowadzące do destabilizacji rynków pracy, ograniczenia inwestycji oraz pogłębiania nierówności (Martin, 2012). Zjawiska te często przekładają się na napięcia społeczne, przejawiające się w wykluczeniu, segregacji przestrzennej oraz pogorszeniu jakości życia (Benassi i De Falco, 2025), co zostało wyraźnie uwidocznione w okresie pandemii COVID-19 (Noszczyk i in., 2022). Długofalowy, negatywny wpływ na miasto mają również przemiany demograficzne, takie jak starzenie się społeczeństwa, migracje czy depopulacja (Szaja, 2024; Kazak, 2023). Jednocześnie kryzysy pogłębiają się poprzez niewystarczającą efektywność zarządzania oraz brak spójności polityk publicznych (Mierzejewska i in., 2024). W literaturze przedmiotu coraz częściej podkreśla się, że poszczególne zagrożenia i kryzysy nie występują odrębnie, lecz wzajemnie się wzmacniają, generując złożone i trudne do przewidzenia konsekwencje (Westman i in., 2022). Narastająca kumulacja oraz współzależność współczesnych kryzysów prowadzi do zwiększenia wrażliwości systemów miejskich oraz ograniczenia ich zdolności do stabilnego

funkcjonowania (Lawrence i in., 2024). Wielowymiarowość i dynamiczny charakter współczesnych zagrożeń wymuszają konieczność zmiany dotychczasowych modeli rozwoju miast oraz poszukiwania nowych paradygmatów zarządzania miejskiego. W odpowiedzi na te wyzwania coraz większe znaczenie przypisuje się koncepcji odporności miejskiej (Sharifi, 2020).

Pojęcie odporności miejskiej (urban resilience) wywodzi się z nauk ekologicznych i oznacza zdolność systemu do absorpcji zakłóceń, adaptacji oraz utrzymania kluczowych funkcji mimo występujących kryzysów (Holling, 1973; Walker i in., 2004). W odniesieniu do miast podkreśla się dodatkowo zdolność do uczenia się i transformacji w odpowiedzi na zmieniające się warunki rozwoju (Meerow i in., 2016). Ujęcie to akcentuje dynamiczny i wielopoziomowy charakter odporności, obejmujący zarówno infrastrukturę, środowisko, jak i wymiar społeczny. W konsekwencji, odporność miejska postrzegana jest nie jako stan, lecz jako proces ciągłego dostosowywania się do zmiennych uwarunkowań środowiskowych i społeczno-gospodarczych (Pendall i in., 2010).

Kryzysy w literaturze przedmiotu łączone są z koncepcją odporności miejskiej, ta z kolei odnosi się między innymi do cyklu adaptacyjnego (Folke i in., 2010). Koncepcja cyklu adaptacyjnego zaproponowana przez Hollinga i Gundersona (2001) opisuje dynamikę zmian w miastach, poprzez cztery następujące po sobie fazy: eksploracji, konsolidacji, zniszczenia i odnowy. Faza eksploracji oznacza okres dynamicznego wzrostu i poszukiwania nowych ścieżek rozwoju przy wysokiej elastyczności systemu miejskiego. Faza konsolidacji to etap stabilizacji i utrwalania struktur, któremu towarzyszy spadek zdolności adaptacyjnych. Faza zniszczenia polega na załamaniu dotychczasowego porządku w wyniku pojawiających się kryzysów. Faza odnowy obejmuje reorganizację systemu i tworzenie nowych, bardziej odpornych na kryzysy struktur rozwojowych. W tym ujęciu proces przechodzenia między fazami bywa interpretowany jako analogiczny do zjawisk degradacji oraz ponownej aktywizacji obszarów miejskich (np. poprzez rewitalizację), choć nie oznacza prostego powrotu do wcześniejszego stanu, lecz raczej jego przekształcenie (Marcus i Colding, 2023).

W czasie pojawiających się kryzysów klimatycznych, zdrowotnych czy środowiskowych, zieleń miejska działa jako infrastruktura adaptacyjna ograniczając np. ryzyko powodzi czy pozytywnie wpływając na zdrowie psychiczne mieszkańców. W związku z tym tereny zieleni redukują skalę destabilizacji systemu miejskiego i tworzą

swoistą zieloną odporność (Vargas-Hernández i Zdunek-Wielgołaska, 2021). Równie ważne znaczenie w cyklu adaptacyjnym wyróżnianym w ramach odporności miejskiej pełni proces rewitalizacji, który odpowiada przede wszystkim fazie odnowy systemu. Rewitalizacja przekształca zdegradowane obszary a także odbudowuje funkcje społeczne i gospodarcze. W logice cyklu adaptacyjnego kryzys urbanistyczny, będący podstawą do przeprowadzenia procesu rewitalizacji, identyfikowany jest z fazą utraty stabilności. Sam proces tożsamy jest z fazą odbudowy w ramach cyklu adaptacyjnego (Marcus i Colding, 2023). Po poprawnie przeprowadzonym procesie rewitalizacji miasto lub jego część pełni często nowe funkcje (Bernat, 2020), które odpowiadają aktualnym potrzebom przestrzennym, a także potrzebom mieszkańców (Roberts i Sykes, 1999), tym samym podnosząc odporność systemu miejskiego.

Problematyka odporności miejskiej należy obecnie do jednego z dynamicznie rozwijających się nurtów badań nad współczesnym rozwojem miast. Jej genezy upatruje się w teorii odporności ekosystemów zaproponowanej przez Hollinga (1973), a następnie rozwijanej przez Hollinga i Gundersona (2001), Walkera i in. (2004) oraz Folke (2006). Równolegle z badaniami nad odpornością rozwijał się nurt badań nad rolą ekosystemów miejskich oraz terenów zieleni w budowaniu odporności miast. W tym zakresie fundamentalne znaczenie mają prace zespołowe Elmqvista (2013), McPhearsona (2016), Kabisch (2017) oraz Haase (2017). Badacze ci wskazują, że tereny zieleni stanowią jeden z podstawowych elementów systemu społeczno-ekologicznego miasta, zwiększając jego zdolność do adaptacji wobec zmian klimatu, ekstremalnych zjawisk pogodowych oraz presji urbanizacyjnej. Szczególne miejsce zajmują publikacje McPhearsona i in. (2015, 2016), w których wskazuje się, że odporność miasta jest kształtowana poprzez usługi ekosystemowe dostarczane przez zieleń miejską, obejmujące regulację klimatu lokalnego, retencję wód opadowych, poprawę jakości powietrza, ochronę bioróżnorodności oraz wzmacnianie dobrostanu mieszkańców. Podobne stanowisko prezentują Kabisch i in. (2017), podkreślając znaczenie rozwiązań opartych na przyrodzie jako narzędzia zwiększającego odporność miast wobec zmian klimatu.

Znaczący nurt badań koncentruje się na terenach zieleni, którym przypisuje się rolę podstawowego elementu wzmacniającego odporność miejską. Istotny wkład w rozwój tej problematyki wnieśli Mell (2017) czy Hansen i Pauleit (2014). W badaniach tych podkreśla się, że zielona infrastruktura nie stanowi jedynie zbioru terenów zieleni (takich jak m.in. parki, zieleńce, promenady, bulwary, ogrody botaniczne, zieleń towarzysząca drogom), lecz

sieć powiązanych przestrzeni pełniących równocześnie funkcje ekologiczne, społeczne i ekonomiczne (Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody). Pomimo znacznego rozwoju badań światowych nadal dominują opracowania analizujące pojedyncze funkcje terenów zieleni. Najczęściej dotyczą one wpływu zieleni na mikroklimat (Bowler i in., 2010; Gill i in., 2007), retencję wód opadowych (Demuzere i in., 2014), jakość powietrza (Nowak i Dwyer, 2007) czy ograniczanie efektu miejskiej wyspy ciepła (Solatini i Sharifi, 2017). Znacznie rzadziej podejmowane są natomiast badania integrujące wszystkie te funkcje. Coraz częściej zwraca się uwagę, że odporność miasta powinna być analizowana jako właściwość całego systemu społeczno-ekologicznego, a nie suma pojedynczych usług ekosystemowych (Schewenius i in., 2014).

W Polsce badania nad odpornością miejską rozwijają się zdecydowanie wolniej niż w krajach Europy Zachodniej. Do autorów podejmujących problematykę odporności należą między innymi Mierzejewska i Wdowicka (2018) oraz Masik (2022). Istotnym opracowaniem porządkującym problematykę odporności miejskiej w polskiej literaturze jest przegląd autorstwa Masika (2022), prezentujący ewolucję pojęcia oraz jego zastosowania w badaniach geograficznych. Badania bezpośrednio odnoszące odporność miejską do terenów zieleni należą natomiast do stosunkowo nielicznych. Na szczególną uwagę zasługują prace Dobrzańskiej z zespołem (2022), którzy analizowali znaczenie zieleni osiedlowej dla zwiększania odporności Wrocławia po doświadczeniach pandemii COVID-19. Autorzy wskazali, że odpowiednio zaprojektowane tereny zieleni mogą zwiększać odporność środowiskową i społeczną miasta, jednak potencjał ten pozostaje nadal niewystarczająco wykorzystywany w praktyce planistycznej. Podobne ujęcie terenów zieleni w kontekście pandemii prezentują Noszczyk i in. (2022) czy Gorzelany i in. (2023).

Dotychczasowe badania wskazują, że tereny zieleni odgrywają kluczową rolę w kształtowaniu odporności miast. Ich znaczenie wykracza poza dostarczanie pojedynczych usług ekosystemowych i powinno być rozpatrywane w kontekście funkcjonowania całego systemu miejskiego.

1.2. Zidentyfikowana luka badawcza

Dotychczasowe badania wskazują, że tereny zieleni są istotnym elementem funkcjonowania systemów miejskich (Senetra i in., 2018), a ich znaczenie zależy nie tylko od samej obecności zieleni, lecz również od jej cech, struktury i rozmieszczenia w przestrzeni miasta

(Wang i in., 2024; Labib i in., 2020). Analizy prowadzone w różnych obszarach badawczych potwierdzają jednocześnie znaczenie konkretnych właściwości terenów zieleni dla różnych aspektów funkcjonowania mieszkańców i miasta (Kondo i in., 2018). Reyes-Riveros i in. (2021), dokonując systematycznego przeglądu 153 artykułów, wykazali związki pomiędzy cechami terenów zieleni, w tym ich strukturą, wielkością i udziałem pokrycia roślinnością, a różnymi wymiarami dobrostanu mieszkańców. Z kolei Twohig-Bennett i Jones (2018), w systematycznym przeglądzie obejmującym 143 badania, wykazali szeroki zakres korzystnych związków pomiędzy zielenią a zdrowiem mieszkańców.

Jednocześnie dotychczasowy dorobek badawczy jest zróżnicowany pod względem analizowanych właściwości terenów zieleni oraz pełnionych przez nich funkcji i usług ekosystemowych (Haase i in., 2014). Część badań koncentruje się na strukturze i organizacji przestrzennej terenów zieleni, inne na ich związkach z dobrostanem i zdrowiem mieszkańców, a kolejne na ich znaczeniu dla odporności miejskiej (Afriyanie i in., 2020). W tym ostatnim aspekcie coraz częściej podkreśla się potrzebę ujmowania zieleni jako elementu szerszego systemu społeczno-ekologicznego (Huff i in., 2020). Reynolds i in. (2022) proponują ramy umożliwiające analizę zielonej infrastruktury z perspektywy społecznych i ekologicznych cech systemów odpornych, wskazując na potrzebę systemowego podejścia do wykorzystania i planowania zieleni na rzecz odporności miejskiej. Badania te stanowią istotny krok w kierunku powiązania terenów zieleni z problematyką odporności miejskiej, jednak koncentrują się przede wszystkim na rozwijaniu ram konceptualnych i identyfikowaniu cech zieleni istotnych z perspektywy odporności. W mniejszym stopniu prowadzą natomiast do połączenia różnych wymiarów funkcjonowania terenów zieleni oraz ich empirycznej analizy w odniesieniu do konkretnych skal i przestrzeni miejskich.

Na podstawie przeanalizowanej literatury naukowej można wskazać, że luka badawcza dotyczy przede wszystkim niewystarczającego rozpoznania relacji pomiędzy terenami zieleni a odpornością miejską. Dotychczasowe badania dostarczają wiedzy na temat różnych właściwości i funkcji terenów zieleni, jednak ich znaczenie dla budowania odporności systemów miejskich wymaga dalszego wyjaśnienia. Ważne jest również rozwijanie podejść pozwalających na interpretację tych relacji w szerszym kontekście funkcjonowania systemu miejskiego. Istotnym obszarem wymagającym dalszych analiz pozostaje również badanie relacji pomiędzy terenami zieleni a odpornością miejską

w różnych skalach przestrzennych. Zestawienie wyników uzyskiwanych na poziomie całego miasta, osiedli mieszkaniowych oraz konkretnych przestrzeni poddanych przekształceniom pozwala spojrzeć na tereny zieleni z perspektywy różnych poziomów funkcjonowania systemu miejskiego. Zidentyfikowana luka badawcza dotyczy zatem nie tyle małej liczby badań łączących tereny zieleni z odpornością miejską, ile ograniczonego rozpoznania tej relacji w sposób umożliwiający jej interpretację. Rozprawa odpowiada na tę lukę poprzez połączenie wyników analiz prowadzonych w różnych wymiarach i skalach, których synteza stanowi podstawę autorskiej propozycji ram interpretacyjnych pojęcia zielonej odporności miejskiej. Proponowane ujęcie integruje cztery wzajemnie powiązane wymiary: środowiskowy, odnoszący się do stabilności terenów zieleni; infrastrukturalno-przestrzenny, obejmujący ich strukturę; społeczny, związany z percepcją terenów zieleni przez użytkowników oraz administracyjno-zarządczy, dotyczący pożądanej koncepcji rozwoju terenów zieleni.

2. Cel badania

Celem rozprawy doktorskiej jest identyfikacja i wyjaśnienie roli terenów zieleni w procesie przemian współczesnych miast ze szczególnym uwzględnieniem ich wkładu w budowanie odporności miejskiej.

Cel badania zrealizowany został w ramach czterech warstw: teoretycznej, metodycznej, empiryczno-poznawczej oraz aplikacyjnej.

W warstwie **teoretycznej** autor opierał się na przeglądzie literatury dotyczącej funkcji i roli terenów zieleni w miastach ze szczególnym uwzględnieniem koncepcji odporności miejskiej **(A1, A2, A4)** oraz znaczenia przemian zachodzących we współczesnych miastach **(A3)**. Punktem wyjścia do badań było założenie, że miasto stanowi złożony system społeczno-ekologiczny. W systemie tym wzajemne relacje pomiędzy środowiskiem przyrodniczym, infrastrukturą techniczną oraz strukturami społecznymi wpływają na jego zdolność do funkcjonowania w warunkach różnorodnych zakłóceń. W odpowiedzi na zidentyfikowaną lukę badawczą w rozprawie autor w ostatnim artykule **(A4)** zaproponował autorskie ramy interpretacyjne zielonej odporności miejskiej *(green urban resilience)*, które integrują perspektywę środowiskową, przestrzenną i społeczną w analizie roli zieleni miejskiej w procesach transformacji współczesnych miast.

Warstwa **metodyczna** pracy obejmowała szereg metod, które zostały dobrane w celu wielopoziomowej realizacji celu badania. W ramach dysertacji wykorzystano metody stosowane w różnych dziedzinach nauki, m.in. ścisłych i przyrodniczych (**A1**), społecznych (**A2, A3**) czy humanistycznych (**A4**). W każdym z artykułów wchodzących w skład cyklu wykorzystane zostały indywidualnie dobrane metody, które odpowiadały potrzebom badania. Szczegółowy opis metod oraz wykorzystanych danych znajduje się w podrozdziale 2.3. i 2.3.1. niniejszego autoreferatu.

Warstwa **empiryczno-poznawcza** badań koncentrowała się na analizie procesów zachodzących w przestrzeni miejskiej, ze szczególnym uwzględnieniem roli terenów zieleni w budowaniu odporności miejskiej. Badania empiryczne obejmowały analizę struktury i przekształceń terenów zieleni w dwóch europejskich miastach **(A1)**. Istotnym elementem warstwy empirycznej było także uwzględnienie perspektywy użytkowników przestrzeni miejskiej dotyczącej terenów zieleni miejskiej **(A3)**. Perspektywa ta uwzględniona została w kontekście oceny projektów rewitalizacyjnych, których efektem było wskazanie najlepszych według mieszkańców projektów tj. tych, które najlepiej odpowiadają na ich potrzeby. W badaniach warstwa empiryczna obejmowała analizę terenów zieleni z perspektywy konkretnych osiedli mieszkaniowych w celu określenia ich roli oraz strategii rozwoju **(A2)**. Ostatnim działaniem w ramach omawianej warstwy była analiza bibliometryczna prowadząca do identyfikacji wymiarów odporności miejskiej, z uwzględnieniem zielonego wymiaru koncepcji **(A4)**. W rezultacie badania empiryczne prowadziły do sformułowania wniosków dotyczących roli terenów zieleni, stanowiąc jednocześnie podstawę do rozwinięcia i dookreślenia zielonej odporności miejskiej.

Warstwa **aplikacyjna** pracy polegała na przetestowaniu zestawu komplementarnych badań umożliwiających ocenę roli zieleni miejskiej w procesach transformacji współczesnych miast oraz budowaniu ich odporności. Podejście to łączyło m.in. analizę zmian struktury przestrzennej terenów zieleni **(A1)**, ocenę stabilności ekologicznej **(A1)** oraz analizę percepcji terenów zieleni **(A2 i A3)**. Takie podejście może być stosowane w analizach porównawczych, a także stanowi podstawę do formułowania narzędzi badawczych i rekomendacji dla polityki miejskiej w zakresie rewitalizacji, adaptacji do zmian klimatu, odporności miejskiej oraz rozwoju terenów zieleni.

2.1. Założenia, pytania i zadania badawcze

Pierwszym etapem procesu badawczego było określenie założeń badawczych oraz sformułowanie pytań i zadań badawczych. Następnie dokonano operacjonalizacji najważniejszych pojęć tj. tereny zieleni i odporność miejska. W dalszej części zebrane zostały niezbędne dane i opracowane procedury postępowań badawczych. W końcowej części badania nastąpiła weryfikacja przyjętych założeń oraz odpowiedź na pytania badawcze.

Na podstawie sformułowanego powyżej celu badania i przeprowadzonego przeglądu literatury określone zostały następujące założenia badawcze:

- **Z1** – Rozwój terenów zieleni stanowi podstawę do budowania miasta odpornego na kryzysy. **(A1)**
- **Z2** – Tereny zieleni na osiedlach mieszkaniowych pełnią ważne role środowiskowe i społeczne, a ich odpowiednie zagospodarowanie wzmacnia potencjał tych obszarów w zakresie budowania odporności miejskiej. **(A2)**
- **Z3** – Projekty rewitalizacyjne ukierunkowane na rozwój terenów zieleni stanowią istotny mechanizm przekształcania i odnowy przestrzeni oraz służą integracji społecznej. **(A3)**
- **Z4** – Odporność miejska jest koncepcją wielowymiarową, w której jeden z wymiarów - środowiskowy związany jest z rolą terenów zieleni w mieście i stanowi jej ważny komponent. **(A4)**

Na podstawie założeń badawczych określono pytania badawcze. Sformułowanie poniższych pytań badawczych pozwoliło na zrealizowanie przyjętego celu pracy.

- P1 - Jak zmienia się powierzchnia i jakie są kierunki przekształceń terenów zieleni miejskiej w warunkach postępującej urbanizacji? **(A1)**
- P2 - Jaka jest pożądana strategia rozwoju terenów zieleni na osiedlach mieszkaniowych ukierunkowana na tworzenie odporności miejskiej? **(A2)**
- P3 - Jak oceniane są projekty rewitalizacyjne dotyczące terenów zieleni przez użytkowników przestrzeni miejskiej? **(A3)**
- P4 - Jakie są aktualne wymiary koncepcji odporności miejskiej i jak przedstawiane są w ramach tej koncepcji kwestie związane z terenami zieleni? **(A4)**

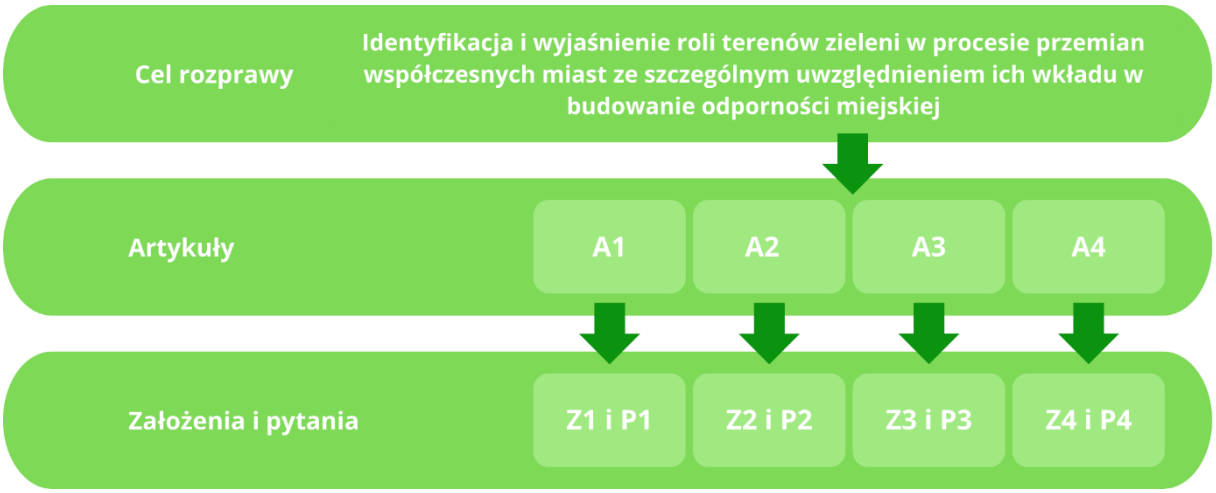
Zadania badawcze pozwalające zrealizować założony cel pracy doktorskiej określone zostały w tabeli 2.

Tab. 2. Zadania badawcze realizowane w ramach dysertacji

Artykuł	Zadania badawcze
A1	• analiza literatury dotyczącej terenów zieleni i stabilności ekologicznej miast • przygotowanie bazy danych oraz przeprowadzenie analiz przestrzennych • analiza transformacji terenów zieleni • wyliczenie współczynnika stabilności ekologicznej
A2	• analiza literatury dotyczącej terenów zieleni • przygotowanie scenariusza i przeprowadzenie spacerów urbanistyczno-architektonicznych w Toruniu i Krakowie • sformułowanie mocnych i słabych stron oraz szans i zagrożeń terenów zieleni na osiedlach mieszkaniowych w Toruniu i w Krakowie • wybór strategii rozwoju terenów zieleni w oparciu o metodę SWOT/TOWS
A3	• analiza literatury dotyczącej procesu rewitalizacji w Polsce • analiza Lokalnego Programu Rewitalizacji Miasta Torunia na lata 2007-2015 • opracowanie i przeprowadzenie postępowania metodą MMDM w oparciu o projekty rewitalizacyjnej realizowane na Bydgoskim Przedmieściu w Toruniu
A4	• analiza literatury dotyczącej koncepcji odporności miejskiej • zdefiniowanie aktualnych wymiarów odporności miejskiej w oparciu o aktualną literaturę naukową i metodę analizy sieciowej słów kluczowych • szczegółowa analiza wymiaru środowiskowego odporności miejskiej w oparciu o metody analizy sieciowej słów kluczowych

Źródło: opracowanie własne; ***A1*** *– Artykuł „An analysis of urban green spaces: a case study in Poland and Slovakia”;* ***A2 –*** *„Green spaces in Polish large prefabricated housing estates developed in the socialist era” ;* ***A3*** *– Artykuł „Evaluation of revitalisation projects in Poland using the Maslin Multi-Dimensional Matrix: heading towards green & social revitalisation”;* ***A4 –****„Bibliometric analysis of research on urban resilience: towards a systematic framework”.*

Na rycinie 1 przedstawiony został schemat badania i relacja przyjętych założeń i pytań badawczych w stosunku do artykułów wchodzących w skład dysertacji.



Ryc. 1. Schemat badania
Źródło: opracowanie własne.

Zaprezentowane powyżej pytania i zadania badawcze zostały tak sformułowane, aby wskazać i zidentyfikować rolę terenów zieleni w procesie przemian współczesnych miast ze szczególnym uwzględnieniem ich wkładu w budowanie odporności miejskiej. Obejmują one zarówno wymiar przestrzenno-strukturalny (zmiany powierzchni i struktury terenów zieleni), funkcjonalno-społeczny (ocena ich znaczenia w procesach rewitalizacji oraz percepcja użytkowników), jak i wymiar strategiczny (identyfikacja uwarunkowań rozwoju oraz kierunków kształtowania polityki), a także ujęcie teoretyczne (miejsce zieleni w koncepcji odporności miejskiej).

2.2. Zakres przestrzenny badania

Zakres przestrzenny badania obejmowały wybrane obszary miejskie (laboratoria miejskie) reprezentujące różne skale i typy struktur przestrzennych. Przyjęcie wielopoziomowego ujęcia przestrzennego wynika z założenia, że tereny zieleni są ważne na różnych poziomach organizacji przestrzeni miejskiej, tj. od skali całego miasta, poprzez układy osiedlowe, aż po konkretne przestrzenie lokalne.

W celu uporządkowania zakresu przestrzennego badań przyjęto systematykę opartą na trzech poziomach analizy: poziomie makroprzestrzennym (miasta), mezoprzestrzennym (osiedla) oraz mikroprzestrzennym (wybrane obszary osiedla).

Na poziomie **makroprzestrzennym** analiza dotyczyła struktury przestrzennej całego miasta (studia przypadków: Toruń i Koszyce) oraz zmian w pokryciu terenu, ze szczególnym uwzględnieniem rozmieszczenia i udziału terenów zieleni w powierzchni miasta. Na tym poziomie możliwe było określenie ogólnych kierunków przekształceń środowiska miejskiego. Analiza pozwoliła również na porównanie badanych miast pod

względem ich struktury przestrzennej oraz roli terenów zieleni w kształtowaniu odporności miejskiej. Na poziomie **mezoprzestrzennym** badanie koncentrowało się na wybranych strukturach miejskich, takich jak osiedla mieszkaniowe (Rubinkowo I w Toruniu oraz Bronowice Nowe w Krakowie). Na tym poziomie możliwe było bardziej szczegółowe rozpoznanie relacji pomiędzy rozmieszczeniem terenów zieleni a ich funkcjonowaniem w przestrzeni miejskiej. Analiza na poziomie **mikroprzestrzennym** została ograniczona do wybranych obszarów osiedla Bydgoskie Przedmieście w Toruniu poddanych rewitalizacji, mających szczególne znaczenie w strukturze przestrzenno-funkcjonalnej.

Tak przyjęta systematyka zakresu przestrzennego umożliwiła integrację analiz prowadzonych na różnych poziomach przestrzennych. Wpłynęła także na bardziej kompleksowe zrozumienie roli terenów zieleni w procesach transformacji współczesnych miast oraz w kształtowaniu ich odporności.

2.3. Metody i dane wykorzystane w badaniu

W ramach dysertacji wykorzystano triangulację metod badawczych, co wynikało ze złożoności celu pracy oraz wielowymiarowego charakteru analizowanego zagadnienia. W każdym z czterech powiązanych tematycznie artykułów zastosowano odmienny zestaw metod (Tab. 3) pozwalających odpowiedzieć na postawione pytania badawcze. Opracowanie procedury badawczej wymagało przygotowania i integracji złożonego zestawu danych pierwotnych i wtórnych, które poddawane zostały następnie dalszym analizom.

Tab. 3. Dane oraz metody badań

Artykuł	Wykorzystana metoda badawcza	Wykorzystane dane
A1	• kwerenda literaturowa • analizy przestrzenne z użyciem środowiska GIS • analiza wskaźnikowa	• dane wektorowe pochodzące z Urban Atlas • dane z Bazy Danych Obiektów Topograficznych BDOT10k (Polska) • dane z Państwowej Administracji Geodezji i Katastru Republiki Słowackiej
A2	• kwerenda literaturowa • spacer urbanistyczno-architektoniczny • analiza SWOT/TOWS	• dane statystyczne • dane przestrzenne (BDOT10k, ortofotomapy) • obserwacje terenowe (spacery badawcze)
A3	• kwerenda literaturowa • Maslin Multi-Dimensional Matrix	• dane o projektach realizowanych w ramach Lokalnego Programu Rewitalizacji Torunia na lata 2007-2015 • dane pochodzące z przeprowadzenia warsztatów w ramach procedury MMDM
A4	• kwerenda literaturowa • analiza bibliometryczna	• baza danych w postaci artykułów naukowych indeksowanych w Web of Science oraz Scopus

Źródło: opracowanie własne; ***A1*** *– Artykuł „An analysis of urban green spaces: a case study in Poland and Slovakia”;* ***A2 –*** *„Green spaces in Polish large prefabricated housing estates developed in the socialist era” ;* ***A3*** *– Artykuł „Evaluation of revitalisation projects in Poland using the Maslin Multi-Dimensional Matrix: heading towards green & social revitalisation”;* ***A4 –*** *„Bibliometric analysis of research on urban resilience: towards a systematic framework”*

2.3.1. Wykorzystane dane

W ramach przeprowadzonych badań wykorzystano szeroki zakres danych dobranych indywidualnie do każdego artykułu wchodzącego w cykl publikacji. W ramach danych pierwotnych użytych w badaniu wskazać można w szczególności dane pochodzące z warsztatów przeprowadzonych w listopadzie 2020 roku w ramach procedury MMDM **(A3)** oraz dane pochodzące ze spaceru architektoniczno-urbanistycznego o charakterze inwentaryzacyjnym, realizowanym w kwietniu, czerwcu i lipcu 2023 roku **(A2)**. Wykorzystane dane pierwotne posłużyły do weryfikacji założeń badawczych **Z2** i **Z3** oraz odpowiedzi na pytania badawcze **P2** i **P3**.

Do danych wtórnych wykorzystanych w celu weryfikacji założenia **Z1** oraz odpowiedzi na pytanie badawcze **P1** zaliczyć należy dane wektorowe dotyczące pokrycia

i użytkowania terenu pochodzące z bazy Urban Atlas dla lat 2006, 2012 oraz 2018 **(A1)**. Na podstawie przygotowanego zbioru danych wektorowych dokonano syntezy i wyodrębnienia kategorii terenów zieleni, która w swoim zakresie obejmowała dane dla trzech klas pochodzących z Urban Atlas: *green urban areas (zieleń miejska), sport and leisure facilities (tereny sportowo-rekreacyjne) oraz forest (lasy)*. Obok danych wektorowych z Urban Atlas w artykule **(A1)** wykorzystane zostały dane z Bazy Danych Obiektów Topograficznych (Polska) oraz dane z Państwowej Administracji Geodezji i Katastru Republiki Słowackiej. Dane te posłużyły do przygotowania map oraz analizy wskaźnikowej w oparciu o współczynnik stabilności ekologicznej.

W ramach artykułu **(A2)** wykorzystano dane statystyczne, takie jak liczba mieszkańców dwóch osiedli będących poligonami badawczymi (Rubinkowo I w Toruniu oraz Bronowice Nowe w Krakowie). Obok danych statystycznych wykorzystane zostały także dane pochodzące z analizy ortofotomap Torunia i Krakowa oraz Bazy Danych Obiektów Topograficznych umożliwiające oszacowanie przybliżonej powierzchni terenów zieleni w ramach analizowanych osiedli. Przygotowany zestaw danych statystycznych i przestrzennych posłużył do zweryfikowania założenia **Z2** oraz pytania **P2.** Wśród danych wtórnych wskazać należy także dane o projektach realizowanych w ramach Lokalnego Programu Rewitalizacji Torunia na lata 2007-2015 **(A3)**. Dane te były podstawą do przygotowania postępowania badawczego metodą MMDM, które pozwoliło na weryfikację założenia **Z3** oraz uzyskanie odpowiedzi na pytanie **P3**.

Przy kompletowaniu danych wtórnych istotne było także zgromadzenie i opracowanie zbioru metadanych publikacji naukowych dotyczących odporności miejskiej **(A4)**. Dane te zostały pozyskane z bazy Scopus oraz Web of Science, a następnie wykorzystane do analiz bibliometrycznych weryfikujących założenie **Z4** i odpowiadających na pytanie **P4**.

2.3.2. Metody badawcze

W dysertacji dokonano triangulacji metod badawczych. Do realizacji celu badania wykorzystano zarówno metody ilościowe, jak i jakościowe. Do metod ilościowych zaliczyć należy analizy przestrzenne z użyciem środowiska GIS, analizę wskaźnikową oraz analizę bibliometryczną. W badaniu wykorzystano metody jakościowe, takie jak kwerenda literaturowa, spacer urbanistyczno-architektoniczny o charakterze inwentaryzacyjnym oraz metodę SWOT/TOWS. W badaniu wykorzystano także metodę Maslin Multi-Dimensional Matrix, która zaliczana jest do metod analizy wielowymiarowej.

W ramach każdej z publikacji wchodzących w skład dysertacji **(A1-A4)** wykonano kwerendę literaturową obejmującą celowe wyszukiwanie, gromadzenie oraz selekcjonowanie pozycji literaturowych (Orłowska i in., 2017). Kwerenda literaturowa obejmowała analizę literatury naukowej dotyczącej określonych w poszczególnych artykułach zagadnieniach ze szczególnym uwzględnieniem tematyki terenów zieleni i odporności miejskiej. Celem prowadzonych kwerend literaturowych było zidentyfikowanie najważniejszych koncepcji, trendów i badań, które stworzyły podstawy teoretyczne dla planowanych badań własnych.

W artykule A1 *"An analysis of urban green spaces: a case study in Poland and Slovakia"* wykorzystano metody analiz przestrzennych z wykorzystaniem środowiska GIS. W tym celu dla dwóch miast Torunia i Koszyc pobrane zostały dane wektorowe pochodzące z ogólnodostępnego serwisu danych o pokryciu terenu Urban Atlas publikowanego w ramach Copernicus Land Monitoring Service. Wykorzystanie metody analiz przestrzennych pozwoliło na określenie procentowego udziału terenów zieleni w ogólnej powierzchni analizowanych miast. Wykorzystując narzędzia geoprzetwarzania, przygotowana została analiza zmian powierzchni terenów zieleni. W tym samym artykule wykorzystano także metodę analizy wskaźnikowej w oparciu o współczynnik stabilności ekologicznej (CES) według Míchal (1985) oraz Miklós (1986). Według Míchala (1985) współczynnik stabilności ekologicznej oblicza się jako stosunek powierzchni terenów ekologicznie stabilnych do powierzchni terenów ekologicznie niestabilnych:

$$CES = \frac{S}{L}$$

gdzie:

S – łączna powierzchnia terenów ekologicznie stabilnych (np. lasy, trwałe użytki zielone, łąki i pastwiska, zbiorniki wodne, mokradła, sady),

L – łączna powierzchnia terenów ekologicznie niestabilnych (np. grunty orne, tereny zabudowane i silnie przekształcone antropogenicznie).

Współczynnik stabilności ekologicznej według Míchala (1985) stanowi syntetyczny miernik służący do oceny stopnia równowagi ekologicznej badanego obszaru. Określa on relację pomiędzy powierzchnią terenów ekologicznie stabilnych a terenami niestabilnymi, tym samym umożliwiając ocenę stopnia antropogenicznego przekształcenia przestrzeni oraz potencjału środowiska do zachowania i odtwarzania procesów ekologicznych (Chromčák i in., 2021), które są ważne w kontekście budowania odporności miejskiej.

Rozwinięciem i uszczegółowieniem współczynnika stabilności ekologicznej według Míchala jest współczynnik stabilności ekologicznej według Miklósa (1986). Współczynnik ten uwzględnia nie tylko podział na tereny stabilne i niestabilne, ale również ekologiczną wartość (znaczenie) poszczególnych form użytkowania terenu, wyrażoną za pomocą współczynników wagowych:

$$CES = \frac{\sum_{i=1}^{n}(p_i * k_i)}{P}$$

gdzie:

pi – powierzchnia rodzaju użytkowania terenu,
ki – współczynnik znaczenia ekologicznego przypisany do danego rodzaju użytkowania,
P – całkowita powierzchnia badanego obszaru,
n – liczba analizowanych kategorii użytkowania terenu.

Celem obliczania współczynnika stabilności ekologicznej według Miklósa (1986) jest kompleksowa ocena stopnia stabilności ekologicznej środowiska miejskiego z uwzględnieniem zróżnicowanej wartości ekologicznej poszczególnych form użytkowania terenu. W przeciwieństwie do metody Míchala (1985), która dzieli tereny jedynie na stabilne i niestabilne, metoda Miklósa uwzględnia fakt, że różne formy pokrycia terenu w odmiennym stopniu wpływają na funkcjonowanie środowiska miejskiego.

W artykule A2 *„Green spaces in Polish large prefabricated housing estates developed in the socialist era”* wraz z kwerendą literaturową wykorzystano metodę spaceru urbanistyczno-architektonicznego o charakterze inwentaryzacyjnym oraz metodę analizy SWOT/TOWS. Urbanistyczno-architektoniczny spacer badawczy o charakterze inwentaryzacyjnym jest metodą wywodzącą się z badań etnograficznych, zaliczaną do tzw. badań w działaniu (Gierczyk i Dobosz, 2016). Umożliwia bezpośrednie poznanie i ocenę przestrzeni poprzez wielozmysłową obserwację badanego obszaru, identyfikację jego cech oraz dokumentację elementów zagospodarowania (Dihingia i in., 2022). Metoda pozwala na analizę aspektów, które trudno uchwycić wyłącznie za pomocą tradycyjnych metod badawczych, a jednocześnie uwzględnia aktywną rolę badanego miejsca w procesie poznawczym (Martini, 2020). Procedura spaceru urbanistyczno-architektonicznego o charakterze inwentaryzacyjnym obejmuje określenie celu badania, wyznaczenie trasy, przeprowadzenie spaceru zgodnie z wcześniej przygotowanym scenariuszem oraz opracowanie i analizę zgromadzonego materiału. W ramach spaceru ocenione zostały m.in.

elementy zagospodarowania przestrzeni, infrastruktura, tereny zieleni na badanych osiedlach, co pozwala na kompleksową diagnozę badanego obszaru. Równocześnie z metodą spaceru urbanistyczno-architektonicznego zastosowana została metoda SWOT/TOWS.

Analiza SWOT/TOWS jest metodą badawczą służącą do oceny badanego zjawiska poprzez identyfikację jego mocnych i słabych stron oraz szans i zagrożeń wynikających z uwarunkowań wewnętrznych i zewnętrznych (Tylińska, 2005). Ze względu na swoją uniwersalność znajduje zastosowanie w wielu dyscyplinach naukowych, m.in. w planowaniu strategicznym, zarządzaniu środowiskiem oraz gospodarce przestrzennej (Ghazinoory i in., 2011). Procedura badawcza zrealizowana w ramach artykułu obejmowała następujące etapy: identyfikację czynników SWOT, wybór najistotniejszych elementów i nadanie im wag metodą sędziów kompetentnych, analizę wzajemnych zależności pomiędzy czynnikami, agregację uzyskanych wyników oraz wyznaczenie strategii rozwoju na podstawie macierzy SWOT/TOWS (Helms i Nixon, 2010; Leigh, 2009). Efektem zastosowania metody był wybór pożądanej strategi rozwoju terenów zieleni na osiedlach mieszkaniowych. Tak określona strategia stanowi podstawę do formułowania kierunków dalszego rozwoju terenów zieleni ukierunkowanego na tworzenie odporności miejskiej.

W artykule A3 *„Evaluation of revitalisation projects in Poland using the Maslin Multi-Dimensional Matrix: heading towards green & social revitalisation”* główną wykorzystaną metodą badawczą była metoda Maslin Multi-Dimensional Matrix (MMDM). Metoda MMDM jest narzędziem matematyczno-statystycznym wykorzystywanym do wielokryterialnej oceny i klasyfikacji obiektów badań (Montanari i Bracker, 1986; Puffitt & Prince, 2001). W kontekście niniejszego badania ocenie, według tej metody, poddane zostały projekty rewitalizacyjne realizowane na obszarze Bydgoskiego Przedmieścia w Toruniu. Metoda MMDM umożliwia analizę stopnia, w jakim realizowane przedsięwzięcia odpowiadają na zidentyfikowane potrzeby mieszkańców oraz pozwala na ich uszeregowanie według skuteczności osiągania założonych celów. Metoda znajduje zastosowanie nie tylko w badaniach dotyczących przekształceń miejskich, ale również m.in. w ekonomii i zarządzaniu projektami (Puffitt, 1993).

Uzyskane oceny w ramach procedury badawczej metodą MMDM pozwalają na klasyfikację projektów rewitalizacyjnych do jednej z czterech kategorii:

- projekty o najwyższej skuteczności, które powinny być kontynuowane i monitorowane (premium quality),
- projekty wymagające dalszego wspierania i rozwoju (good quality),

- projekty wymagające modyfikacji (think and change),
- projekty niespełniające oczekiwań i rekomendowane do wycofania (run away).

W ten sposób powstaje ranking projektów rewitalizacyjnych, które najlepiej odpowiadają na potrzeby mieszkańców oraz charakteryzują się wysoką skutecznością osiągania założonych celów rewitalizacyjnych

W artykule A4 *„Bibliometric analysis of research on urban resilience: towards a systematic framework”* główną metodą badawczą była analiza bibliometryczna w oparciu o sieciowe analizy współwystępowania powiązań między słowami kluczowymi. Metody analiz bibliometrycznych polegają na ilościowym badaniu publikacji naukowych oraz relacji między nimi w celu identyfikacji trendów i wymiarów badawczych, dominujących tematów, struktur wiedzy oraz dynamiki rozwoju danej dyscypliny. Metoda ta wykorzystuje dane bibliograficzne, takie jak cytowania, autorstwo, słowa kluczowe czy współpracę naukową (De Bellis, 2009). Metody analiz bibliograficznych bazują także na sieciowej analizie wykorzystującej zasadę współwystępowania słów kluczowych (keyword co-occurrence analysis), która pozwala na identyfikację i zbadanie częstotliwości występowania określonych słów kluczowych (Chen, 2017). W badaniu posłużono się narzędziem VOSviewer. Umożliwia ono przejrzystą identyfikację relacji pomiędzy słowami kluczowymi oraz grupowanie ich w klastry tematyczne, co pozwala uchwycić strukturę badanego obszaru naukowego i wyznaczyć dominujące wymiary (Van Eck i Waltman, 2010). Metody analiz bibliometrycznych wykorzystane w artykule pozwoliły na wskazanie aktualnych wymiarów koncepcji odporności miejskiej w oparciu o najnowsze badania. Dzięki metodzie analiz bibliometrycznych wskazane zostały także podwymiary wymiaru środowiskowego odporności miejskiej.

3. Wyniki przeprowadzonych badań

3.1. A1 – „Analiza terenów zieleni w miastach: studium przypadku w Polsce i na Słowacji”

Celem artykułu była analiza zmian powierzchni i struktury terenów zieleni miejskiej oraz identyfikacja kierunków ich przekształceń w dwóch miastach Europy Środkowej, w Toruniu (Polska) i Koszycach (Słowacja). Dokonana została także analiza oceny stabilności

ekologicznej badanych miast w celu określenia wpływu zachodzących zmian na rozwój terenów zieleni i przestrzeni miejskiej.

Badania przeprowadzono w trzech etapach. W pierwszym wykonano kwerendę literatury oraz analizę dokumentów strategicznych dotyczących terenów zieleni, w celu rozpoznania kierunków aktualnych polityk miejskich. W drugim etapie przeprowadzono analizy przestrzenne z wykorzystaniem systemów informacji geograficznej (GIS), bazujące na danych Urban Atlas z lat 2006, 2012 oraz 2018. Analizy obejmowały określenie udziału terenów zieleni w strukturze przestrzennej miasta, ocenę zmian ich powierzchni oraz identyfikację kierunków przekształceń poszczególnych kategorii terenów zieleni. W trzecim etapie oceniona została stabilność ekologiczna obu miast poprzez obliczenie współczynnika stabilności ekologicznej (CES) według metod Míchala (1985) oraz Miklósa (1986). Wykorzystanie analizy wskaźnikowej umożliwiło określenie stopnia równowagi pomiędzy elementami stabilnymi i niestabilnymi przestrzeni miejskiej.

Przeprowadzone badania wykazały, że przekształcenia terenów zieleni są powiązane z kształtowaniem odporności miasta, co znajduje odzwierciedlenie w ich związku ze współczynnikiem stabilności ekologicznej. W analizowanych miastach odnotowano wzrost udziału terenów zieleni w strukturze użytkowania terenu, jednak wynikał on niemal wyłącznie ze zwiększenia powierzchni lasów. Równocześnie zaobserwowano zmniejszenie powierzchni zieleni miejskiej *(green urban areas)* oraz terenów sportowo-rekreacyjnych *(sport and leisure facilities)*. Analiza kierunków przekształceń wykazała, że obszary te były przeznaczane przede wszystkim pod funkcje przemysłowe, komercyjne i inne formy zagospodarowania związane z rozwojem urbanistycznym.

Uzyskane wyniki wskazują, że charakter zachodzących przekształceń terenów zieleni może mieć istotne znaczenie dla potencjału miasta w zakresie budowania odporności. Analiza kierunków zmian potwierdziła ponadto, że rozwój nowych funkcji przemysłowych i komercyjnych w miastach koncentrował się w znacznej mierze na obszarach zieleni miejskiej *(green urban areas)*. Jednocześnie skala tworzenia nowych terenów zieleni miejskiej *(green urban areas)* była niewielka i ograniczała się głównie do przekształceń obszarów półnaturalnych. Oznacza to, że sam wzrost powierzchni terenów zieleni nie jest wystarczającym warunkiem wzmacniania odporności miasta. Równie istotne jest zachowanie istniejących terenów zieleni oraz ograniczanie ich przekształceń na cele inwestycyjne, ponieważ to kierunek i skala zmian w strukturze użytkowania terenu decydują

o możliwościach utrzymania odporności miasta w warunkach postępującej urbanizacji. Zmiany w strukturze terenów zieleni wpływają także na stabilność ekologiczną przestrzeni miejskich, co wykazały badania przeprowadzone w oparciu o wskaźnik stabilności ekologicznej (CES).

3.2. A2 – „Tereny zieleni na osiedlach mieszkaniowych budowanych w okresie socjalizmu w Polsce”

Celem artykułu było określenie perspektyw rozwoju terenów zieleni na osiedlach mieszkaniowych w Polsce na przykładzie osiedli wybudowanych w okresie socjalizmu, tj. Rubinkowo I w Toruniu oraz Bronowice Nowe w Krakowie. W ramach artykułu zidentyfikowane zostały mocne i słabe strony terenów zieleni, a także ich szanse i zagrożenia. Efektem przeprowadzenia badań było wskazanie najbardziej pożądanej strategii rozwoju terenów zieleni na analizowanych osiedlach mieszkaniowych.

Badania oparto na zastosowaniu dwóch metod badawczych. Pierwszą z nich był urbanistyczno-architektoniczny spacer badawczy o charakterze inwentaryzacyjnym, przeprowadzony na obu osiedlach. Pozwolił on na ocenę zagospodarowania przestrzeni, rodzaju i stanu zieleni, infrastruktury rekreacyjnej, miejsc integracji mieszkańców oraz występujących problemów, takich jak presja inwestycyjna czy degradacja terenów zieleni. Drugą metodą była analiza SWOT/TOWS, która umożliwiła identyfikację mocnych i słabych stron terenów zieleni (uwarunkowań wewnętrznych) oraz szans i zagrożeń wynikających z uwarunkowań zewnętrznych. Następnie określono najbardziej odpowiednią strategię rozwoju terenów zieleni na badanych osiedlach.

Wyniki badań wykazały, że tereny zieleni na analizowanych osiedlach charakteryzują się dużym udziałem w powierzchni osiedli (Kraków - 50%; Toruń - 57%). Ich największym atutem okazało się tworzenie korzystnego mikroklimatu, sprzyjającego budowaniu odporności miasta, a także zapewnianie mieszkańcom łatwego dostępu do przestrzeni rekreacyjnych i integracyjnych. Jednocześnie wskazano na problemy związane z niewystarczającą pielęgnacją części terenów zieleni, występowaniem gatunków uciążliwych dla mieszkańców oraz rosnącą presją inwestycyjną prowadzącą do ograniczania powierzchni terenów zieleni. Analiza SWOT/TOWS wykazała, że najkorzystniejszym kierunkiem rozwoju terenów zieleni na osiedlach mieszkaniowych jest strategia konkurencyjna, zakładająca wykorzystanie pojawiających się szans przy jednoczesnym

ograniczaniu zidentyfikowanych słabości. W praktyce oznacza to przede wszystkim wykorzystanie potencjału terenów zieleni do rozwoju inicjatyw społecznych i aktywizacji mieszkańców oraz tworzenia nowych form zieleni i rozwiązań opartych na przyrodzie. W artykule wskazano również, że działania te mogą przyczyniać się do poprawy jakości i ciągłości systemu zieleni, ograniczenia degradacji terenów zieleni oraz zmniejszenia skutków presji inwestycyjnej. Szczególne znaczenie przypisano także zwiększaniu udziału mieszkańców w procesach zarządzania terenami zieleni, ponieważ oddolne inicjatywy społeczne mogą wspierać utrzymanie ich wysokiej jakości.

Wyniki badań wskazują ponadto, że właściwie zagospodarowane tereny zieleni sprzyjają integracji społecznej, zapewniają powszechnie dostępne przestrzenie rekreacji i aktywności dla różnych grup mieszkańców oraz wzmacniają środowiskowy wymiar odporności miejskiej poprzez kształtowanie korzystnego mikroklimatu oraz rozwój błękitno-zielonej infrastruktury. W badaniu podkreślono, że odpowiednio planowane i właściwie zarządzane tereny zieleni mogą jednocześnie zwiększać odporność środowiskową i społeczną osiedli mieszkaniowych oraz stanowić istotny element zrównoważonego rozwoju współczesnych miast.

3.3. A3 – „Ocena projektów rewitalizacyjnych w Polsce z wykorzystaniem wielowymiarowej matrycy Maslina: w kierunku zielonej i społecznej rewitalizacji”

Głównym celem artykułu była ocena skuteczności realizacji projektów rewitalizacyjnych na przykładzie wybranych obszarów osiedla Bydgoskie Przedmieście w Toruniu, poddanych rewitalizacji. Celem szczegółowym było zbadanie, jak użytkownicy zrewitalizowanej przestrzeni oceniają przeprowadzone działania oraz w jakim stopniu zaspokoiły one potrzeby lokalnej społeczności.

Badania zostały przeprowadzone w trzech etapach. W pierwszym dokonano przeglądu literatury dotyczącej rewitalizacji oraz metod jej oceny. W drugim etapie przeanalizowano Lokalny Program Rewitalizacji (LPR) Miasta Torunia na lata 2007–2015, identyfikując najważniejsze problemy osiedla Bydgoskie Przedmieście, takie jak zły stan techniczny budynków, nieuporządkowana przestrzeń publiczna, niski poziom aktywności gospodarczej, dezintegracja społeczna oraz niskie poczucie bezpieczeństwa. Trzeci etap badania stanowiła analiza projektów rewitalizacyjnych oraz warsztaty z wykorzystaniem

metody Maslin Multi-Dimensional Matrix (MMDM), w których uczestniczyło 60 osób reprezentujących różne grupy społeczne związane z Bydgoskim Przedmieściem.

Uczestnicy warsztatów oceniali wagę zidentyfikowanych problemów w przestrzeni osiedla (wynikających z LPR) oraz skuteczność realizacji poszczególnych projektów rewitalizacyjnych w ich rozwiązywaniu. Na podstawie uzyskanych ocen przygotowano macierz MMDM, która pozwoliła przyporządkować projekty rewitalizacyjne do czterech kategorii jakości "premium quality", "good quality", "think and change", "run away". Do najwyższej kategorii *premium quality* zakwalifikowane zostały przedsięwzięcia łączące działania przestrzenne z celami społecznymi, integracyjnymi i środowiskowymi takimi jak rewitalizacja zabytkowego Parku Miejskiego na Bydgoskim Przedmieściu i Michayland - Fantastyczne Miasteczko Dzieciaków**.** Te projekty w największym stopniu realizowały cele rewitalizacji oraz odpowiadały na potrzeby lokalnej społeczności. Wysokie oceny wspomnianych dwóch projektów wskazują, że o skuteczności rewitalizacji decydowała nie tylko poprawa jakości przestrzeni publicznej, ale również stworzenie miejsca sprzyjającego budowaniu relacji społecznych i aktywizacji mieszkańców. Otrzymane wyniki potwierdziły, że tereny zieleni mogą pełnić funkcję trwałej platformy integracji społecznej, a ich rewitalizacja prowadzi jednocześnie do odnowy przestrzeni oraz wzmacniania więzi społecznych. Równie wysokie oceny (*good quality)* otrzymały projekty dotyczące zieleni takie jak rewitalizacja ogrodu botanicznego czy renowacja przedszkola miejskiego nr 4. Z kolei projekty koncentrujące się wyłącznie na modernizacji infrastruktury, takie jak przebudowa ulicy Mickiewicza, a także inicjatywy adresowane do wąskich grup odbiorców (bieg im. Jana Pawła II, projekt "Kulturalna Rewitalizacja"), zostały ocenione niżej *(kategoria think and change oraz run away).* W opinii mieszkańców w ograniczonym stopniu przyczyniały się do rozwiązywania problemów zidentyfikowanych w procesie rewitalizacji oraz nie odpowiadały na najważniejsze potrzeby lokalnej społeczności.

Uzyskane wyniki wskazują zatem, że największą skuteczność rewitalizacyjną osiągają przedsięwzięcia, które integrują odnowę terenów zieleni z działaniami społecznymi. Metoda MMDM umożliwiła identyfikację tego typu projektów oraz wykazała wysoką przydatność w ocenie stopnia realizacji celów rewitalizacji z perspektywy mieszkańców.

3.4. A4 – “Analiza bibliometryczna badań nad odpornością miejską: w kierunku systematyzacji”

Celem artykułu było przeprowadzenie przeglądu literatury oraz analizy bibliometrycznej badań dotyczących koncepcji odporności miejskiej. W artykule dokonano identyfikacji dominujących kierunków badawczych. Na tej podstawie opracowane zostały uporządkowane ramy analityczne przedstawiające najważniejsze wymiary odporności miejskiej.

W badaniu dokonano przeglądu literatury oraz określono zakres czasowy analiz obejmujący lata 2010–2025. Podstawą do prowadzenia analiz bibliometrycznych było wybranie bazy danych, na podstawie której były przeprowadzone dalsze działania. W tym celu dokonano weryfikacji, ile razy fraza *“urban resilience”*, będąca główną frazą wyszukiwawczą występowała odpowiednio w tytule, abstrakcie i słowach kluczowych, w bazie Scopus i Web of Science. Do dalszych badań wybrano bazę Scopus, ze względu na najliczniejsze sumaryczne występowanie głównej frazy wyszukiwawczej (Web of Science 4662 rekordy; Scopus 6812 rekordów). Kolejny krok polegał na analizie ilościowej liczby publikacji, analizie współwystępowania słów kluczowych *(keyword co-occurrence analysis)* oraz analizie sieci powiązań z wykorzystaniem programu VOSviewer. Tak przeprowadzona procedura badawcza pozwoliła wyodrębnić główne klastry tematyczne i określić dominujące wymiary odporności miejskiej. Przeprowadzona została także pogłębiona analiza środowiskowego wymiaru odporności miejskiej.

Zastosowanie analizy ilościowej oraz analizy sieci współwystępowania słów kluczowych umożliwiło identyfikację dominujących kierunków badań nad odpornością miejską. Wyniki analiz wykazały, że badania koncentrują się wokół pięciu podstawowych wymiarów odporności miejskiej: administracyjno-zarządczego, infrastrukturalno-przestrzennego, środowiskowego, ekonomicznego oraz społecznego. Ważnym efektem badania było wskazanie wymiaru zakłóceniowego, który pełni funkcję nadrzędnego wymiaru spajającego pozostałe wymiary. Analizy wykazały również, że kwestie środowiskowe należą do istotnych obszarów badań nad odpornością miejską. W literaturze dominują jednak zagadnienia związane z zarządzaniem oraz infrastrukturą. Wskazuje to na potrzebę silniejszej integracji aspektów środowiskowych z pozostałymi wymiarami odporności.

Na podstawie przeprowadzonych analiz dokonano także próby określenia autorskiej ramy interpretacyjnej zielonej odporności miejskiej *(green urban resilience)*. W ramach wskazanej zielonej odporności miejskiej tereny zieleni stanowią jeden z kluczowych komponentów wzmacniających zdolność miast do tworzenia ich bardziej odpornych. Zielona odporność miejska może być definiowana jako zdolność systemu miejskiego do utrzymania i poprawy jakości życia mieszkańców poprzez świadome wykorzystanie i wzmacnianie zasobów przyrodniczych w procesach planowania, zarządzania i adaptacji. Stanowi ona podejście holistyczne, łączące perspektywę ekologiczną, klimatyczną, przestrzenną i planistyczną, w którym przyroda nie jest jedynie elementem uzupełniającym, lecz kluczowym czynnikiem kształtującym długofalową stabilność i rozwój miasta.

4. Dyskusja

Wyniki przeprowadzonych badań wskazują, że tereny zieleni pełnią we współczesnym mieście funkcję znacznie szerszą niż wyłącznie estetyczna czy rekreacyjna. Analizy wykonane w ramach rozprawy potwierdzają obserwowany w literaturze zwrot w kierunku postrzegania zieleni miejskiej jako elementu infrastruktury odpornościowej miasta, wspierającej jego zdolność do adaptacji wobec współczesnych kryzysów klimatycznych, społecznych i zdrowotnych.

Wyniki artykułu **A1** pokazują, że procesy urbanizacyjne prowadzą do dualnych przekształceń terenów zieleni. Z jednej strony obserwowany był wzrost udziału lasów, natomiast z drugiej następowała redukcja zieleni miejskiej oraz terenów sportowo-rekreacyjnych na rzecz infrastruktury transportowej i zabudowy. Podobne procesy opisują Li i in. (2022), wskazując na stopniowe ograniczania terenów zieleni przez intensyfikację urbanizacji. Uzyskane wyniki potwierdzają również obserwacje Rigolon i in. (2021), zgodnie z którymi utrata lokalnych terenów zieleni ma szczególnie silny wpływ na codzienne funkcjonowanie mieszkańców miast. W przypadku Torunia widoczna była przede wszystkim presja infrastrukturalna związana z rozwojem układu drogowego, co prowadziło do fragmentacji zieleni miejskiej. Jednocześnie wyższe wartości współczynnika stabilności ekologicznej w Koszycach potwierdzają ustalenia Ahern (2011), wskazujące, że duże kompleksy zieleni i terenów półnaturalnych zwiększają odporność środowiskową miasta oraz jego zdolność adaptacji wobec zmian klimatycznych. Uzyskane wyniki wskazują również, że ocena znaczenia terenów zieleni dla odporności miejskiej nie powinna

ograniczać się wyłącznie do analizy ich powierzchni. Współczesne badania podkreślają, że odporność miast wynika z jakości powiązań między terenami zieleni, sposobu ich zarządzania oraz zdolności do dostarczania wielu usług ekosystemowych jednocześnie (Elmqvist i in., 2013; McPhearson i in., 2015; Meerow i in., 2016; Frantzeskaki i Bush, 2021).

Badania przedstawione w artykule **A2** dowodzą, że osiedla mieszkaniowe powstałe w okresie socjalizmu posiadają istotny potencjał adaptacyjny wynikający z dużego udziału terenów biologicznie czynnych oraz wysokiej dostępności zieleni. Wyniki te wpisują się w ustalenia Haaland i van den Bosch (2015), którzy wskazują, że tereny zieleni na osiedlach mieszkaniowych mogą pełnić ważną funkcję klimatyczną i społeczną we współczesnych miastach. Problem dogęszczania zabudowy kosztem przestrzeni biologicznie czynnych jest obecnie szeroko analizowany w literaturze, jako jedno z głównych zagrożeń dla odporności środowiskowej miast europejskich (Haase, 2015). Jednocześnie wyniki badań wskazujące na dużą aktywność oddolnych inicjatyw mieszkańców, takich jak miniogrody czy lokalne działania zazieleniające, potwierdzają obserwacje Elmqvist i in., (2019), zgodnie z którymi lokalne formy zaangażowania społecznego wzmacniają odporność społeczną i zdolności adaptacyjne miasta. Wyniki badań znajdują również potwierdzenie w analizach Jima (2004), który wykazał, że zachowanie odpowiedniej ilości i jakości zieleni na osiedlach mieszkaniowych wpływa nie tylko na poprawę warunków środowiskowych, ale również zwiększa funkcjonalność przestrzeni oraz komfort życia mieszkańców. Oznacza to, że ochrona terenów biologicznie czynnych powinna być traktowana jako integralny element planowania rozwoju osiedli, zwłaszcza w warunkach nasilającej się presji inwestycyjnej.

Wyniki badań przeprowadzonych w ramach artykułu **A3** wskazują, że użytkownicy najwyżej oceniali projekty rewitalizacyjne związane z terenami zieleni oraz poprawą jakości przestrzeni publicznych. Wyniki te są zgodne z badaniami Honey-Rosés i in. (2021), Venter i in. (2020), Noszczyk i in. (2022) czy Gorzelany i in. (2023), którzy wykazali wzrost znaczenia zieleni miejskiej, która zaczęła być postrzegana nie tylko jako przestrzeń rekreacyjna, lecz również jako infrastruktura zdrowia psychicznego i społecznego. Wysoka ocena rewitalizacji Parku Bydgoskiego potwierdza obserwacje Bell i in. (2018) dotyczące krajobrazów terapeutycznych, czyli przestrzeni wspierających regenerację psychiczną i dobrostan mieszkańców. Uzyskane wyniki wskazują również, że użytkownicy oczekują rewitalizacji integrującej funkcje środowiskowe i społeczne, a nie wyłącznie działań

infrastrukturalnych. Potwierdza to obserwowany w literaturze zwrot ku tzw. ekorewitalizacji, polegający na zwiększaniu roli zielonej infrastruktury w procesach odnowy miast (Rogatka i in., 2018). Uzyskane wyniki są również zgodne z ustaleniami Tzoulasa i in. (2007), którzy wskazują, że zielona infrastruktura pełni jednocześnie funkcje ekologiczne, społeczne i zdrowotne, stanowiąc istotny element poprawy jakości życia w miastach. Wysoka ocena projektów rewitalizacyjnych opartych na terenach zieleni potwierdza, że mieszkańcy dostrzegają wartość rozwiązań integrujących aspekty środowiskowe z potrzebami społecznymi, co wpisuje się we współczesne rezylientne podejście do planowania i odnowy obszarów miejskich.

Badania bibliometryczne przedstawione w artykule **A4** wskazują natomiast, że współczesne badania nad odpornością miejską wciąż koncentrują się głównie na wymiarze administracyjno-zarządczym i infrastrukturalno-przestrzennym, podczas gdy wymiar środowiskowy pozostaje słabiej reprezentowany. Jednocześnie przeprowadzona analiza wykazała istotne znaczenie w ramach środowiskowego wymiaru odporności miejskiej takich pojęć jak zielona infrastruktura, zmiany klimatu, analizy przestrzenne czy planowanie miejskie. Sieciowe powiązania w ramach wymiaru środowiskowego pomiędzy takimi kategoriami jak zielona infrastruktura oraz zmiany klimatu wskazują na postępującą ekologiczną reinterpretację odporności miejskiej. Zbieżność ta znajduje silne oparcie w literaturze. Zuniga-Teran i in. (2020) podkreślają, że zielona infrastruktura stanowi kluczowy komponent odporności poprzez zdolność do redukcji m.in. ryzyka powodziowego, łagodzenia efektu miejskiej wyspy ciepła i poprawy jakości powietrza. Z kolei Grimm i in. (2008) wskazują, że miasta funkcjonują jako złożone systemy, których stabilność zależy od jakości relacji między komponentem przyrodniczym i społecznym. Uzyskane wyniki są zgodne z analizami Sharifi (2020), który wskazuje na dominację badań dotyczących zarządzania kryzysowego oraz infrastruktury technicznej w literaturze dotyczącej urban resilience. Przeprowadzone analizy bibliometryczne są również zbieżne z ustaleniami Borie i in. (2019), którzy wykazali, że badania nad odpornością miejską ewoluują od podejścia skoncentrowanego na zarządzaniu kryzysowym i infrastrukturze technicznej w kierunku szerszego ujęcia uwzględniającego aspekty środowiskowe, społeczne i adaptacyjne.

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Wraz z rozwojem nauki, a także technologii rozwijają się różne, innowacyjne metody analizy terenów zieleni i budowania ich roli w odporności miasta. Należy zatem zwrócić uwagę, że postępujący rozwój sztucznej inteligencji *(Artificial Intelligence, AI)* otwiera nowe możliwości w zakresie planowania, rozwoju i zarządzania terenami zieleni w mieście. Dotychczasowe badania wskazują, że AI wykorzystywana jest przede wszystkim do automatycznej inwentaryzacji zieleni, monitorowania zmian pokrycia terenu, oceny stanu drzew oraz analizy danych teledetekcyjnych, znacząco usprawniając proces pozyskiwania i przetwarzania informacji przestrzennych, a co za tym idzie przyspieszania procesów decyzyjnych (Zhao i in., 2026). Jednocześnie podkreśla się, że potencjał sztucznej inteligencji w strategicznym planowaniu terenów zieleni oraz wspomaganiu decyzji planistycznych pozostaje nadal niewystarczająco wykorzystany (Patil i in., 2024). Rozwój narzędzi integrujących dane środowiskowe, społeczne i przestrzenne z algorytmami AI może w przyszłości stanowić istotne wsparcie dla zarządzania zieloną infrastrukturą oraz planowania działań zwiększających odporność miast na skutki negatywnych zmian klimatu (de Lima Araujo i in., 2021). Stanowi to jeden z najbardziej perspektywicznych kierunków dalszych badań.

5. Wnioski i podsumowanie

Przeprowadzone badania umożliwiły identyfikację i wyjaśnienie roli terenów zieleni w procesie przemian współczesnych miast ze szczególnym uwzględnieniem budowania odporności miejskiej. Postępowanie badawcze obejmowało analizę przekształceń terenów zieleni, ocenę efektów działań rewitalizacyjnych, określenie kierunków rozwoju zieleni na osiedlach mieszkaniowych oraz identyfikację znaczenia wymiaru środowiskowego w aktualnej koncepcji odporności miejskiej. Poszczególne artykuły koncentrują się zatem na różnych rolach, które pełnią tereny zieleni w mieście, w kontekście odporności miejskiej.

Interpretacja wyników artykułu **A1** pozwoliła odpowiedzieć na postawione pytanie badawcze **P1** *"Jak zmienia się powierzchnia i jakie są kierunki przekształceń terenów zieleni miejskiej w warunkach postępującej urbanizacji?"*. W analizowanych miastach odnotowano wzrost udziału terenów zieleni w strukturze użytkowania terenu, jednak wynikał on niemal wyłącznie ze zwiększenia powierzchni lasów. Zieleń miejska przekształcana jest przede wszystkim na rzecz terenów przemysłowych, terenów związanych z rozwojem

mieszkalnictwa i rozwojem układów drogowych. Nowopowstające tereny zieleni stanowią niewielki udział w przestrzeni miasta.

Wnioski płynące z badań w ramach **A1** pozwoliły też pozytywnie zweryfikować przyjęte założenie **Z1** *"Rozwój terenów zieleni stanowi podstawę do budowania miasta odpornego na kryzysy"*. Tereny zieleni, poprzez pełnienie funkcji regulacyjnych i środowiskowych, wzmacniają stabilność systemu miejskiego, zmniejszając jego podatność na negatywne oddziaływania. Stabilność ekologiczna stanowi tym samym jeden z elementów kształtujących odporność miejską. W tym ujęciu stosunek elementów stabilnych i niestabilnych w strukturze przestrzenno-środowiskowej miasta wpływa na sposób i skalę jego reakcji na pojawiające się zakłócenia. Im większa zdolność terenów zieleni do stabilizowania procesów zachodzących w środowisku miejskim, tym większy potencjał miasta do absorpcji zakłóceń i utrzymania ciągłości funkcjonowania. Można zatem wskazać, że odpowiednia ilość i struktura terenów zieleni wzmacnia stabilność ekologiczną, a ta z kolei stanowi podstawę budowania odporności miejskiej.

Wyniki badań zrealizowanych w artykule **A2** pozwoliły na odpowiedź na pytanie badawcze **P2** tj. "*Jaka jest pożądana strategia rozwoju terenów zieleni na osiedlach mieszkaniowych ukierunkowana na tworzenie odporności miejskiej?"*. Analiza wyników w ramach artykułu **A2** wskazała, że najbardziej pożądaną strategią rozwoju terenów zieleni miejskiej na osiedlach mieszkaniowych jest strategia konkurencyjna. Strategia ta polega na wykorzystaniu pojawiających się szans (m.in. możliwość integracji społecznej na terenach zieleni, możliwość rozwoju małej retencji miejskiej na terenach zieleni, wzrost świadomości społecznej dotyczącej roli terenów zieleni w mieście i jej nowych form, możliwość wykorzystania potencjału terenów zieleni do kształtowania pozytywnego brandingu miejskiego), przy jednoczesnej redukcji słabych stron terenów zieleni (m.in. obniżanie jakości życia użytkowników poprzez występowanie gatunków uciążliwych, zły stan części terenów zieleni, częściowo zdewastowane nawierzchnie ciągów komunikacyjnych oraz elementy małej architektury, brak połączenia/powiązania z innymi terenami zieleni w mieście) na osiedlach mieszkaniowych. Przeprowadzony w ramach badania spacer urbanistyczno-architektoniczny
o charakterze inwentaryzacyjnym pozwolił zdiagnozować rolę terenów zieleni na osiedlach mieszkaniowych. Spacer wskazał także, że tereny zieleni na osiedlach mieszkaniowych sprzyjają integracji społecznej oraz mogą stanowić ważny element miejskiej odporności. Syntetyczne ujęcie wyników w ramach analizy SWOT/TOWS i spaceru urbanistycznego

pozwoliło na pozytywną weryfikację i przyjęcie założenia **Z2**, tj. *"Tereny zieleni na osiedlach mieszkaniowych pełnią ważne role środowiskowe i społeczne, a ich odpowiednie zagospodarowanie wzmacnia potencjał tych obszarów w zakresie budowania odporności miejskiej"*.

Wyniki zawarte w artykule **A3** pozwoliły odpowiedzieć na pytanie badawcze **P3** tj. "*Jak oceniane są projekty rewitalizacyjne dotyczące terenów zieleni przez użytkowników przestrzeni miejskiej?".* Wyniki przeprowadzonej analizy wskazały, że projekt dotyczący odnowy terenów zieleni (Rewitalizacja zabytkowego Parku Miejskiego na Bydgoskim Przedmieściu w Toruniu) został najlepiej oceniony przez użytkowników przestrzeni osiedla Bydgoskie Przedmieście i zaklasyfikowany do kategorii *premium quality.* Równie wysoką klasyfikację (*good quality)* otrzymał projekt dotyczący rewitalizacji elementów Ogrodu Zoobotanicznego na Bydgoskim Przedmieściu, co podkreśla wysoką rangę "zielonych projektów rewitalizacyjnych" w zakresie realizacji celów rewitalizacji miasta. Ponadto w kategorii *premium quality* znalazł się projekt typowo społeczny (Michayland - Fantastyczne Miasteczko Dzieciaków), który był realizowany w przestrzeni wspomnianego parku. Wysokie oceny projektów rewitalizacyjnych wskazują, że współrealizacja projektów środowiskowych i społecznych najlepiej odpowiada potrzebom użytkowników przestrzeni. Tym samym wpływają one na przekształcenia i odnowę przestrzeni oraz służą integracji społecznej, co pozwala pozytywnie zweryfikować założenie **Z3** tj. *"Projekty rewitalizacyjne ukierunkowane na rozwój terenów zieleni stanowią istotny mechanizm przekształcania i odnowy przestrzeni oraz służą integracji społecznej"*.

Odpowiadając na pytanie badawcze **P4**, tj. "*Jakie są aktualne wymiary koncepcji odporności miejskiej i jak przedstawiane są w ramach tej koncepcji kwestie związane z terenami zieleni?"* wskazać należy, że w ramach koncepcji odporności miejskiej aktualnie wyróżnić można pięć wymiarów: administracyjno-zarządczy, infrastrukturalno-przestrzenny, środowiskowy, ekonomiczny i społeczny. Wyróżnić można także wymiar nadrzędny - zakłóceniowy, który jest wymiarem spajającym pozostałe. Kwestie związane z terenami zieleni zajmują istotne miejsce w ramach wymiaru środowiskowego, poruszane są w ramach zagadnień takich jak: *green infrastructure* (zielona infrastruktura), *climate change* (zmiany klimatu), *spatial analyses* (analizy przestrzenne) czy *urban planning* (planowanie miejskie/przestrzenne). Z kolei sam wymiar środowiskowy był podstawą do stworzenia ram interpretacyjnych zielonej odporności miejskiej, w której tereny zieleni nie są elementem uzupełniającym, lecz kluczowym czynnikiem kształtującym długofalową stabilność

i rozwój miasta. Tym samym, wnioski płynące z badania pozwoliły na pozytywne zweryfikowanie i przyjęcie założenia **Z4**, tj. **"***Odporność miejska jest koncepcją wielowymiarową, w której jeden z wymiarów - środowiskowy związany jest z rolą terenów zieleni w mieście i stanowi jej ważny komponent".*

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Konkludując, głównym osiągnięciem rozprawy jest oryginalne rozwiązanie problemu naukowego polegającego na identyfikacji i wyjaśnieniu roli terenów zieleni w procesie przemian współczesnych miast ze szczególnym uwzględnieniem budowania odporności miejskiej. Istotne jest także podkreślenie znaczenia komponentu środowiskowego w dynamicznie rozwijającej się koncepcji odporności miejskiej. W tym aspekcie ważne było wskazanie ram interpretacyjnych „zielonej odporności miejskiej" rozumianej jako zdolność systemu miejskiego do utrzymania i poprawy jakości życia mieszkańców poprzez świadome wykorzystanie i wzmacnianie zasobów przyrodniczych w procesach planowania, zarządzania i adaptacji.

Badania w ramach rozprawy wykazały, że współczesne procesy urbanizacyjne prowadzą do ciągłych przekształceń terenów zieleni, zmieniając nie tylko ich powierzchnię, ale przede wszystkim strukturę. W związku z tym ocena potencjału terenów zieleni do tworzenia miejskiej odporności powinna uwzględniać nie tylko wskaźniki ilościowe, lecz także sposób ich zagospodarowania. Jednym z wniosków rozprawy jest stwierdzenie, że skuteczność działań na rzecz rozwoju terenów zieleni zależy od stopnia ich integracji z potrzebami mieszkańców. Wyniki badań dotyczące rewitalizacji przestrzeni miejskiej wskazują, że największą wartość mają rozwiązania łączące funkcje przyrodnicze i społeczne, tworzące przestrzenie sprzyjające integracji czy rekreacji. Tereny zieleni pełnią zatem rolę nie tylko elementu środowiska przyrodniczego, ale również infrastruktury społecznej, która wzmacnia odporność lokalnych społeczności. Analizy wykazały również, że rozwój terenów zieleni powinien być postrzegany jako element długofalowej polityki miejskiej, w tym także przestrzennej, a nie jedynie jako rezultat pojedynczych inwestycji. Zachowanie istniejącego zasobu zieleni, jego systematyczny rozwój oraz ograniczanie presji inwestycyjnej są kluczowymi warunkami wzmacniania potencjału adaptacyjnego miast.

Przeprowadzone badania potwierdzają też, że tereny zieleni w mieście pełnią znacznie szerszą funkcję niż tradycyjnie przypisywana im rola rekreacyjna lub estetyczna. Analizy zawarte w poszczególnych publikacjach obejmowały różnorodne aspekty

funkcjonowania zieleni miejskiej. Przeprowadzone postępowanie badawcze wskazuje na istnienie wspólnego mechanizmu: tereny zieleni w mieście są jednym z kluczowych czynników zwiększających jego zdolność do regeneracji i adaptacji po wystąpieniu zakłóceń oraz transformacji w kierunku bardziej odpornych struktur.

Syntetyczne zestawienie wyników uzyskanych we wszystkich publikacjach umożliwiło wyjście poza wnioski z poszczególnych badań i próbę sformułowania autorskich ram interpretacyjnych zielonej odporności miejskiej *(green urban resilience)*. Zielona odporność miejska stanowi propozycję teoretyczną, która porządkuje uzyskane wyniki i wskazuje, że środowisko przyrodnicze, reprezentowane w miastach głównie przez system terenów zieleni, powinno być traktowane jako jeden z podstawowych filarów odporności współczesnych miast, a nie jedynie jako element uzupełniający ich strukturę funkcjonalno-przestrzenną.

6. Znaczenie uzyskanych wyników dla rozwoju dyscypliny geografia społeczno-ekonomiczna i gospodarka przestrzenna oraz przyszłe kierunki badań

Wkład rozprawy doktorskiej w rozwój dyscypliny geografia społeczno-ekonomiczna i gospodarka przestrzenna można rozpatrywać w czterech wzajemnie powiązanych warstwach: teoretycznej, metodycznej, empiryczno-poznawczej oraz aplikacyjnej.

W warstwie **teoretycznej** rozprawa porządkuje i integruje wiedzę dotyczącą roli terenów zieleni w miastach, osadzając ją w kontekście przemian współczesnych struktur miejskich oraz koncepcji odporności miejskiej **(A1–A4)**. W warstwie tej szczególne znaczenie miało opracowanie autorskich ram interpretacyjnych zielonej odporności miejskiej *(green urban resilience)*, stanowiących próbę określenia relacji pomiędzy terenami zieleni a odpornością miejską. Propozycja ta poszerza dotychczasowe rozumienie odporności miejskiej poprzez wyeksponowanie znaczenia komponentu środowiskowego, a w szczególności terenów zieleni, jako czynnika współkształtującego zdolność miast do adaptacji, regeneracji i reagowania na współczesne wyzwania rozwojowe. W warstwie **metodycznej** wkład rozprawy polega na zastosowaniu zróżnicowanego zestawu metod badawczych, wykorzystywanych w ramach różnych dziedzin nauki, m.in. ścisłych

i przyrodniczych (**A1**), społecznych (**A2, A3**) czy humanistycznych (**A4**), umożliwiając wielopoziomową identyfikację współczesnej roli terenów zieleni. Warstwa **empiryczno-poznawcza** obejmuje natomiast dostarczenie nowych wyników dotyczących struktury i przekształceń terenów zieleni w miastach **(A1)**, ich roli oraz możliwości rozwoju na osiedlach mieszkaniowych **(A2),** znaczenia terenów zieleni w procesach rewitalizacji i oceny tych procesów z perspektywy użytkowników przestrzeni **(A3)**, a także znaczenia wymiaru środowiskowego w koncepcji odporności miejskiej, określonego na podstawie analizy bibliometrycznej **(A4)**. Wyniki te pozwoliły na wskazanie znaczenia terenów zieleni w funkcjonowaniu i transformacji współczesnych miast oraz stworzyły podstawy do stworzenia ram interpretacyjnych zielonej odporności miejskiej. Z kolei w **warstwie aplikacyjnej** wkład rozprawy wiąże się z opracowaniem i przetestowaniem badań łączących m.in. analizę zmian struktury przestrzennej terenów zieleni i stabilności ekologicznej **(A1)** z oceną cech, funkcjonowania i znaczenia terenów zieleni w przestrzeni miejskiej **(A2)** oraz oceną potrzeb i percepcji użytkowników przestrzeni miejskiej **(A3).** Podejście to może znaleźć zastosowanie zarówno w dalszych badaniach porównawczych, jak i w praktyce planowania oraz zarządzania miastami, stanowiąc podstawę do formułowania rekomendacji dotyczących kształtowania terenów zieleni, rewitalizacji miast, adaptacji i mitygacji do zmian klimatu oraz wzmacniania odporności miejskiej w ośrodkach miejskich.

Uzyskane wyniki stanowią argument za szerszym uwzględnieniem komponentu środowiskowego, w tym przede wszystkim terenów zieleni, w badaniach nad odpornością miejską. Kluczowym rezultatem niniejszej rozprawy jest wskazanie potrzeby prowadzenia badań nad zielenią miejską w sposób kompleksowy i wielowymiarowy. Wyniki przedstawione w rozprawie wskazują, że zrozumienie roli terenów zieleni wymaga jednoczesnego uwzględnienia uwarunkowań środowiskowych, przestrzennych, społecznych oraz planistycznych. Takie podejście umożliwia wyjaśnianie procesów zachodzących w miastach oraz funkcjonowania współczesnych systemów miejskich. Uzyskane rezultaty podkreślają konieczność dalszego rozwijania badań nad zagadnieniem *green urban resilience*. Przedstawiona w rozprawie propozycja stanowi punkt wyjścia do opracowania wskaźników umożliwiających ocenę poziomu zielonej odporności miast. Przeprowadzone badania stanowią podstawę do rozwoju dalszych badań teoretycznych, metodologicznych oraz aplikacyjnych.

W przyszłości zasadne jest rozszerzenie analiz o ocenę relacji pomiędzy *green urban resilience* a pozostałymi wymiarami odporności miejskiej, w szczególności wymiarem społecznym, a także opracowanie narzędzi umożliwiających ilościową ocenę zielonej odporności miejskiej. Rozwijanie tych kierunków badań może przyczynić się do pogłębienia wiedzy teoretycznej oraz do wypracowania rozwiązań wspierających zrównoważony rozwój i transformację współczesnych miast.

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8. Załączniki

Artykuł 1.

Starczewski Tomasz, Douša Milan, Lopata Ewelina (2023). An analysis of urban green spaces: a case study in Poland and Slovakia. *Acta Scientiarum Polonorum, Administratio Locorum, 22(1), 85-100.* https://doi.org/10.31648/aspal.8048

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Artykuł 2.

Starczewski Tomasz, Rogatka Krzysztof, Noszczyk Tomasz, Kukulska-Kozieł Anita, Cegielska Katarzyna (2024). Green spaces in Polish large prefabricated housing estates developed in the socialist era. *Journal of Housing and the Built Environment, 39, 1987–2007.* https://doi.org/10.1007/s10901-024-10147-0

Udział: 50%

Artykuł 3.

Starczewski Tomasz, Rogatka Krzysztof, Kowalski Mateusz (2022). Evaluation of revitalisation projects in Poland using the Maslin Multi-Dimensional Matrix: heading towards green & social revitalisation. *Bulletin of Geography. Socio-Economic Series, 55, 123-139.* https://doi.org/10.12775/bgss-2022-0009

Udział: 60%

Artykuł 4.

Starczewski Tomasz (2026). Bibliometric analysis of research on urban resilience: towards a systematic framework. *Civil and Environmental Engineering Reports, 36(3), 12–37. https://doi.org/10.59440/ceer/231519*

Udział: 100%

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AN ANALYSIS OF URBAN GREEN SPACES – A CASE STUDY IN POLAND AND SLOVAKIA

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ABSTRACT

Motives: Rapid urbanisation and the associated spatial, environmental, and economic changes have shifted the researchers' attention to modern cities. Urban green spaces are a vital component of sustainable development because they reduce noise, purify air, improve the local climate and rainwater quality, and provide numerous recreational and relaxation opportunities for the residents. The implementation of the green city concept can have a positive impact on both the environment and the quality of life in a city.
Aim: The aim of the study was to analyse changes in the landscape and surface of urban green spaces, to present the structure of green areas, and to identify change trends in urban green spaces in the Polish city of Toruń and the Slovak city of Košice. The ecological resilience of the studied areas was also examined.
Results: The results of the study indicate that the area occupied by urban green spaces (including urban green areas, sport and leisure facilities, and forests) continues to expand in the studied cities. The rate of increase was much higher, but still low, in the Slovak city of Košice. The analysis of change trends revealed that most industrial and commercial areas were developed in urban green spaces. At the same time, new green spaces were created mainly at the expense of semi-natural areas. Both Toruń and Košice are characterised by average landscape stability.

Keywords: 2030 Agenda, sustainable urban development, green city, landscape management, resilience

INTRODUCTION

By the middle of the century, up to 70% of the world's population will live in urban areas (UN-Habitat, 2022). Urbanisation and climate change require new solutions to maintain and, above all, improve the quality of life in our cities. Cities and towns are beginning to realise the dangers of climate change (Čepelová & Douša, 2018). Green areas of the city are an inseparable element of a sustainable and smart city. In the era of intensifying climate crises, green areas are one of the elements shaping urban

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resilience and ecological stability (Costanza, 1997; Meerow et al., 2016). The analysis and assessment of ecological stability, which is a fundamental component of the idea of urban environmental sustainability, is the foundation for the planning process of urban development (Yukhnovskyi & Zibtseva, 2019). Today, cities occupy less than 3% of the Earth's surface (United Nations, 2018). They are not only engines of growth of a socio-economic nature, but also the site of dynamic environmental transformations. Global sustainability is largely determined by cities, whose current unstable trajectory in terms of urban ecosystems and landscapes requires a focus on ecology and the environment (Wu, 2014). Urbanisation tends to reduce the ratio of land allocated to public green spaces (Noszczyk et al., 2022). However, in the face of contemporary challenges, concern for the environment is an integral part of moving towards sustainable development.

Green spaces are an integral component of the urban landscape and a foundation for the pursuit of sustainable development (Darkwah & Cobbinah, 2014; Łachowski & Łęczek, 2020). They are also an important aspect of adapting to ongoing climate change, building social cohesion and developing the green economy (Hansen et al., 2017). Especially in highly urbanised areas, they are an important component of the urban space and improve it in terms of aesthetics (Szczepańska et al., 2016). Green infrastructure in cities provides maximum ecosystem benefits hence its development is highly desirable nowadays (Augustyn, 2020). In the literature, one can find many studies and documents on the urban green ecosystem and its benefits to the well-being of society (Anguluri & Narayanan, 2017). Thus, greenery in the city also has a leisure and health function as it provides space for relaxation thus enhancing the quality of leisure activities. Prominent exposure to greenery also benefits the psychological well-being of the public (Wang et al., 2019). Just looking at areas of urban greenery creates a sense of relaxation and, as a result, can have a positive impact on stress reduction processes (Elsadek et al., 2020). Studies based on European cities show that by increasing the amount of green areas it is possible to reduce premature deaths and they also have a positive impact on the transformation of cities towards more sustainable and good to live in centres (Barboza et al., 2021). Urban green spaces, complemented by infrastructure in the form of footpaths and bicycle lanes, also provide a place for recreational activities, the positive and important importance of which was particularly recognised during the pandemic (Venter et al., 2021). Studies show that during the pandemic, forests played an important social role in terms of both mental and physical health (Derks et al., 2020). Urban vegetation is also an effective method to promote the reduction of heat intensity (Marando et al., 2022). Applied on a large scale, green spaces, e.g. forests, can have a positive impact on thermal comfort and reduce the urban heat island effect by shaping the shade-induced cooling effect (Virtudes, 2016; Rogatka et al., 2018). Tree crowns create shade, which, together with evapotranspiration, reduces temparature and thus contributes to the thermal comfort of residents (Sun et al., 2021). In addition, green spaces minimise the risk of flooding within the city by reducing surface runoff (Chiabai, 2020). Moreover, greenery in the city located in appropriate places can reduce the negative impact of pollution by creating a natural biological filter that neutralises harmful components from the air (Daniele & Sciacca, 2021; Gubański et al., 2018).

Urban green spaces play an important role in the creation of urban space and the process of reducing the negative effects of urbanization, by maintaining a balance between transportation infrastructure, buildings and green spaces (Harasimowicz, 2018).

According to research by Čepelová and Douša (2018, 2020), many urban areas are already suffering from the negative effects of climate change and other negative consequences. The effects of climate change on urban living conditions will continue to be dramatic, due to rising temperatures, more frequent rains with consequent floods or, conversely, excessive drought. The most successful cities plan to combine the implementation of action plans and investments. However, stand-alone action plans and investments often fail to take full advantage of the synergies

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between optimal coordination and co-ordination of interrelated strategies, subsequent investments and the involvement of urban dwellers. Strong institutional structures and sound financial mechanisms are needed for cities to pursue their green agendas effectively. Both the surveyed cities in both Poland and Slovakia don't have a comprehensive climate strategy to protect the environment and support green spaces. Cities and municipalities are often blocked from implementing measures due to limited political power, low levels of institutional capacity, low levels of stakeholder cooperation, limited fiscal power, poor financial management and insufficient access to finance. Cities need a strong institutional environment that allows their municipalities to operate more efficiently, flexibly and competitively in order to achieve the ambitious green city agenda.

GREEN CITIES – A THEORETICAL APPROACH

Sustainable development has been the subject of much academic debate since the 1960s. Over the following years, many studies have been written on this issue. For the first time the concept was defined in 1987 in the report 'Our Common Future' as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). The issue is described by, among others: Agenda 21 (1992), the Rio Declaration on Environment and Development (1992), the Eight Millennium Goals (2000) and Agenda 2030, which consists of 17 Sustainable Development Goals (UN, 2015). This article focuses on green urban areas (GUAs), which have a direct impact on the three goals (Siragusa et al., 2020): SDG 11 Sustainable cities and communities; SDG 13 Climate action; SDG 15 Living on land.

Sustainable development should not only be considered at the global level, but above all at the local level (Trovato, 2021), which is particularly influenced by GUAs. This is because cities are characterised by having features that intensify the consequences of climate change and extreme weather events (ESPON, 2020). In a post-indurstial world, there has been a shift in the function of cities from industrial to business, innovation or finance, and contemporary cities are both concentrators of global problems and drivers for their solutions (Niemets et al., 2021). One way to support sustainable practices is to provide access to green spaces. Hence, an opportunity to transform cities towards greater sustainability is the concept of green cities. A green city can be defined as „a city that promotes energy efficiency and renewable energy in all its activities, widely promotes green solutions, uses compactness of land with mixed land use and social mixing practices in its planning systems, and anchors its local development in the principles of green growth and equity" (Brilhante & Klaas, 2018). Ecological stability is also an important element of sustainability. It can be defined as the ability of an ecosystem to resist change during disturbances, which is characterised by low variability, i.e. low deviation from the mean level despite changing environmental conditions.

Ecological stability is important in terms of the carrying capacity of the environment. In order for a landscape to withstand greater or lesser changes (stress, strain, etc.), it must achieve certain levels of ecological stability. The ecological stability of the area can be considered directly as one of the key principles of (environmental) sustainability (National Network of Healthy Cities CR, 2022). The landscape is made up of a set of components (=areas) that put together a landscape matrix. The components can be divided into stabilizing and labile. If any activity is carried out in the landscape that could affect the landscape character or functionality of any of its components or the character of the landscape, it is necessary to be able to evaluate the positive or negative consequences. It is an objectification of the definition of the dynamics of the landscape system = the exact numerical expression of changes in the landscape.

The coefficient of ecological stability (CES) represents a ratio number (coefficient), which determines the ratio of so-called stable and unstable areas of landscape-forming elements in the monitored area (Míchal, 1994). In addition, ecological stability is the

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ability of an ecological system to persist even under the influence of a disturbing influence and reproduce its characteristics in the conditions of disturbance from the outside (especially disturbance by humans). CES this expresses how a certain territory can cope with these influences (Kolejka, 2011).

The aim of this article is to analyze changes in the landscape and surface of green areas, to present the structure of green areas and to indicate the directions of transformations in the studied city in Poland and Slovakia.

MATERIALS AND METHODS

Spatial scope of the research

Two European cities – Toruń in Poland and Košice in Slovakia – were used as testing grounds for the comparative study. The authors chose these two cities because of their similar size and population. Toruń is a provincial city with almost 200,000 inhabitants with an area of 115.72 km². Košice is inhabited by nearly 240,000 people – 243.73 km² area. In addition, both cities are regional capitals (in Poland the Kujawsko-Pomorskie Voivodship, in Košice the Košice Country) and thus play the role of a central centre according to Christaller's assumptions. In addition, the article examines green areas, and their nature depends on the climatic conditions. Both cities lie in the same climatic zone, so the structure of green areas in Toruń and Košice will not be detrimental to zonal factors, and comparative analyzes will be possible. However, the overriding criterion for selecting the cities for analysis was their post-industrial character. In the era of global industrialisation, in the space of both cities one could see thriving industrial units, which due to their space-intensive nature intensively consumed green areas.

According to Kocan (2020), the urban landscape, being a dynamic structure, is the most susceptible to all kinds of changes, both at the social and spatial level. In both analysed cities the industry was very active. It was an important part of the economic structure of Toruń and Košice. In Toruń, there was the chemical plant „Polchem", which generated pollution affecting both ecological stability and the condition of green areas. In the case of Košice, the industrial history of the city is still relevant. The largest Slovak steelworks is located in the city – that is why Košice is called „the steel heart of Slovakia".

Research structure, data and methodology

The study was divided into three main stages, i.e. the introductory stage (I); the implementation stage (II) and the concluding stage (III). The introductory stage included an analysis of the literature on urban green areas and European strategic documents such as Agenda 2030, which focuses on sustainable development, with particular emphasis on the role of green areas and ecological stability. The introductory stage ended with defining the purpose and delimitation of the study area. The core of the study, which filled out the entire executive stage, was two research methods:

1. Spatial analyses using GIS;
2. Coefficient of ecological stability (CES).

As a result of the constantly increasing rates of urbanization and construction in both analyzed cities, these two cities were chosen for evaluation. More than 80% of the European population is expected to live in urban areas by 2030 (European Healthy Cities Network, 2022). On the basis of normative values based on data on the density of construction and the degree of urbanization to the total number of inhabitants of the investigated cities, we expect negative results of the ecological stability of the territory and the decline of natural ecosystems in the investigated time period.

GIS METHOD

First, the authors prepared a vector data set from the pan-European land cover database Urban Atlas. These data were downloaded for two years, 2006 and 2018, for two cities that were the testing ground. On the basis of the prepared dataset, one category of area called green spaces was synthesised and separated, which in its structure included land cover data for areas classified in the Urban Atlas as: green urban areas, sport and leisure facilities and forest.

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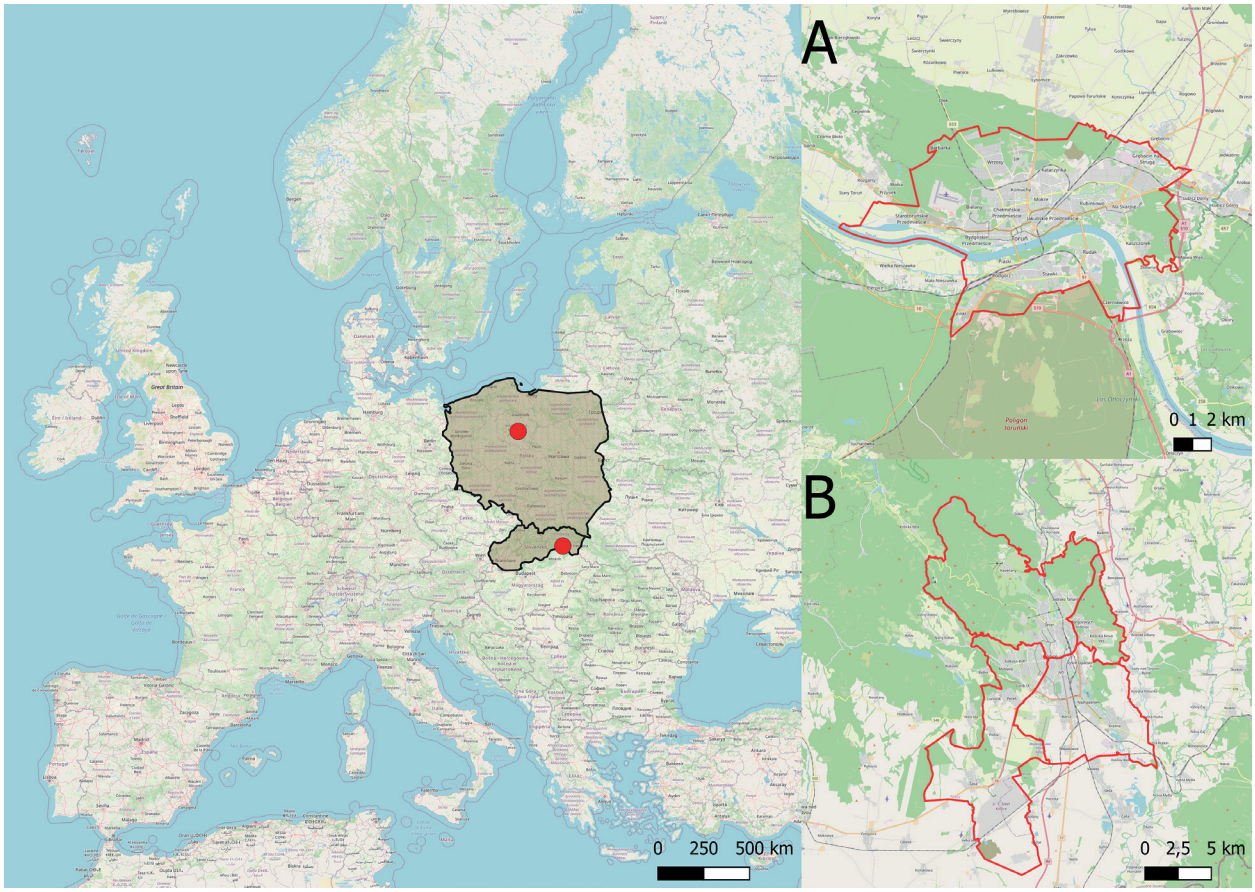


Fig. 1. Spatial scope (A: Toruń; B: Košice)
Source: own preparation.

The prepared vector data were cropped to the borders of the study area, i.e. the administrative borders of Toruń and Košice. In this way, two map compositions were constructed taking into account the coverage of green spaces in Toruń and Košice in the two reference years. Based on these data, the percentage share of green spaces in each city was determined.

In the next step, using geoprocessing tools, an analysis of changes in the area of green spaces in the analysed cities was prepared. In this way, areas which have become green and those which have lost their green character were indicated. Next, on the basis of the prepared map bases, an analysis was made of changes in land cover in selected study plots, i.e. selected urban spaces of Toruń and Košice. The analysis took into account the nature of the change, i.e. in which direction the transformation of green spaces took place. The vector data analysis method was developed and carried out based on the methodology of spatial analyzes with the use of GIS software (Głowacki, 2005).

CES METHOD

Furthermore, qualitative methods were used to fulfil the goal and results, to examine the calculation of the coefficient of the ecological stability of the area according to Míchal (1985) and Miklós (1986). To capture the landscape multifunctionality and to indicate the environmental quality of the area under study, land use provided in parallel by arable land, forests, and bodies of water were studied.

The ratio is determined on the basis of the following elements: Stable elements (WL – woodland;

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WS – water areas and streams; PG – permanent grassland; Pa – pastures; We – wetlands; Or – orchards; Vi – vineyard) and Unstable elements (PL – ploughland; AA – anthropogenic areas; HG – hop-garden). The method of calculating CES is based on a clear and final classification of a landscape element into a group of stable or unstable and does not allow the assessment of the specific state of these elements. The CES value can take the following values and determine the specific ecological resistance:

1. CES ≤ 0.10 areas with maximum disturbance of natural structures, basic ecological functions must be intensively and permanently replaced by technical interventions;
2. 0.10 < CES ≤ 0.30 areas used above average with a clear disruption of natural structures;
3. 0.30 < CES ≤ 1.00 areas intensively used with considerable ecological instability;
4. 1.00 < CES < 3.00 quite balanced landscape in which the technical objects are relatively in accordance with the preserved natural structures;
5. CES ≥ 3.00 natural and nature-friendly landscape (significant predominance of ecologically stable structures) (Míchal, 1985).

At present, there is no longer a purely natural landscape on Earth, because through the changes of the atmosphere, man affects the entire surface of the planet. However, a natural landscape is one whose construction components and processes do not show man-made manifestations.

The tables below contain data on the stable and unstable landscape elements in Košice and Toruń (see Table 1 and Table 2).

The Coefficient of Ecological Stability According to Míchal (1985)

Calculation of CES (in ha) = natural and near-natural areas divided by cultural areas. Specifically, CES = (woodland + water areas and streams + permanent grassland + pastures + wetlands + orchards + vineyard) / (built-up areas + ploughland + hop-garden). The higher the number, the greater the proportion of permanent vegetation areas, the greater the stability of the area (Míchal, 1985). There are many methodologies, but all are based on the same principle. The calculation is always based on the evaluation of the ratio of ecologically stable

Table 1. Stable and unstable elements in the city of Košice district Košice I

Stable elements	Area (in m2)	Unstable elements	Area (in m2)
Woodland	5 154 000	Ploughland	304 000
Water areas (artificial reservoirs, ponds, natural streams)	66 000	Anthropogenic areas (built-up areas)	1 822 000
Permanent grassland	780 000	Hop – garden	not identified
Gardens	391 000		
Researched district area Kosice I. – Džungla, Kavečany, Košice – north, Habitation Ťahanovce, Košice – Old town, City district of Ťahanovce			

Source: The data were obtained from the State Administration of Land Surveying and Cadastre of the Slovak Republic 2022 (The Geodesy, Cartography and Cadastre Authority of the Slovak Republic, 2022).

Table 2. Stable and unstable elements in the city of Toruń

Stable elements	Area (in m2)	Unstable elements	Area (in m2)
Woodland	37 339 335	Ploughland	5 176 207
Water areas (artificial reservoirs, ponds, natural streams)	7 516 318	Anthropogenic areas (built-up areas)	23 824 850
Permanent grassland	28 355 726	Hop-garden	not identified
Gardens	3 593 883		

Source: based on data from The Main Geodesy and Cartography Office (database of topographic objects, DoA: 19.05.2022).

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and ecological labile components of the landscape; individual methodologies differ in the categorization of landscape segments, or in the use of more detailed coefficients.

Miklós ecological stability coefficient (1986)

Unlike the following methodologies, it is not based on the division of areas into stable and unstable, but differentiates their ecological significance by introducing numerical coefficients:

a. pn i – area of individual areas;
b. kpn i – coefficient of ecological significance of areas;
c. p – area of the area of interest (or cadastral);
d. field – 0.14; meadows – 0.62; pasture – 0.68; gardens – 0.5; fruit orchards – 0.3; forests, water, wetlands – 1.00; others – 0.10 (+ lada – 0.62, vineyards – 0.3, rocks – 0.4, line company– 0.4) (Miklós, 1986).

In the last stage of the research – the summary stage, a synthetic analysis of the results of the research was made. This part of the research included mainly the interpretation of changes in the coverage of green spaces in Toruń and Košice and a reference to ecological resilience in both cities.

From the results of the CES of analysed cities in Poland and Slovakia according to the Miklos methodology, they belong into the category of medium stable landscape < 1. Slovak and Poland landscape schools know and use various methodologies. None of them is anchored in the legislation, the closest to the legal norm is the calculation of CES according to Michal, because it is also implemented in the concept of TSES (Territorial systems of ecological stability) = Act No. 114/1992 Coll., § 3 letter a. and landscapes. Because each methodology uses division into different landscape segments and different coefficients, the result may be different, see. result of applied methodologies. Miklós medium stable landscape, Míchal natural and close to nature landscape. However, when planning the use of the landscape and its territory, it is always necessary to pay attention to aspects of sustainable development and try to respect natural structures at the expense of unstable anthropogenic areas.

RESULTS

The results of the research have been aggregated into three thematic blocks:

Block I – analysis of the share of green spaces in general city area
Block II – analysis of directions of green space transformations
Block III – analysis of CES

Block I: analysis of the share of green spaces in general city area

In the base year of 2006, the area of green urban areas in Toruń was 537.84 hectares. In Kosice, on the other hand, green urban areas covered an area of 412.62 hectares. In 2018, both cities saw a decrease in the area of green urban areas, but in the case of Toruń the decrease was much more pronounced. In 2018, green urban areas in Toruń occupied 509.12 hectares. In Kosice, these areas decreased in area by only 2.64 hectares (cf. Table 3).

Another element analysed as part of green spaces was sport and recreation areas. Here, too, both cities

Table 3. Changes in green spaces area

City	GUA 2006 [ha]	GUA 2018 [ha]	Difference GUA 2018–2006 [ha]	SPORT and LEISURE 2006 [ha]	SPORT and LEISURE 2018 [ha]	Difference SPORT and LEISURE 2018–2006 [ha]	FOREST 2006 [ha]	FOREST 2018 [ha]	Difference Forest 2018–2006 [ha]
Toruń	537,84	509,12	-28,72	479,25	466,65	-12,59	3238,27	3380,26	141,99
Košice	412,62	409,98	-2,64	723,53	711,09	-12,44	8130,86	8455,79	324,93

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recorded a decrease in the area of this category of land cover, but in both cities the decrease remained at a similar level, i.e. about 12 hectares.

The only component of green spaces which increased its area was forests. In both of the analysed cities, the area of forest areas increased, noting that in Košice there were more than twice as many forests as in Toruń. All these elements influenced the total share of green spaces in the cities under study.

In 2006, green spaces in Toruń occupied 36.77% of the city area. In Košice, on the other hand, these areas occupied 38.02%. In 2018, the share of green spaces in both cities increased by 0.87% in Toruń and 1.27% in Košice, respectively. This result was mainly influenced by the increase in the area of forests in the cities. Detailed results of changes in the area of green spaces are provided below in tabular form.

Analysing the spatial distribution of changes in the surveyed cities, it should be pointed out that in the case of Košice, these changes were concentrated in the northern and central parts of the city and mostly concerned the creation of new forest areas (Fig. 3). There were no special arrangements and directions in the formation of green spaces. The following figure shows the growth of forests and places where there

Table 4. Green spaces – a comparative approach

City	TOTAL green spaces 2006 [ha]	Share of green areas in the city area 2006	TOTAL green spaces 2018 [ha]	share of green areas in the city area 2018	Percentage difference 2018–2006
Torun	4255,36	36,77%	4356,03	37,64%	0,87%
Košice	9267,01	38,02%	9576,85	39,29%	1,27%

Source: own preparation.

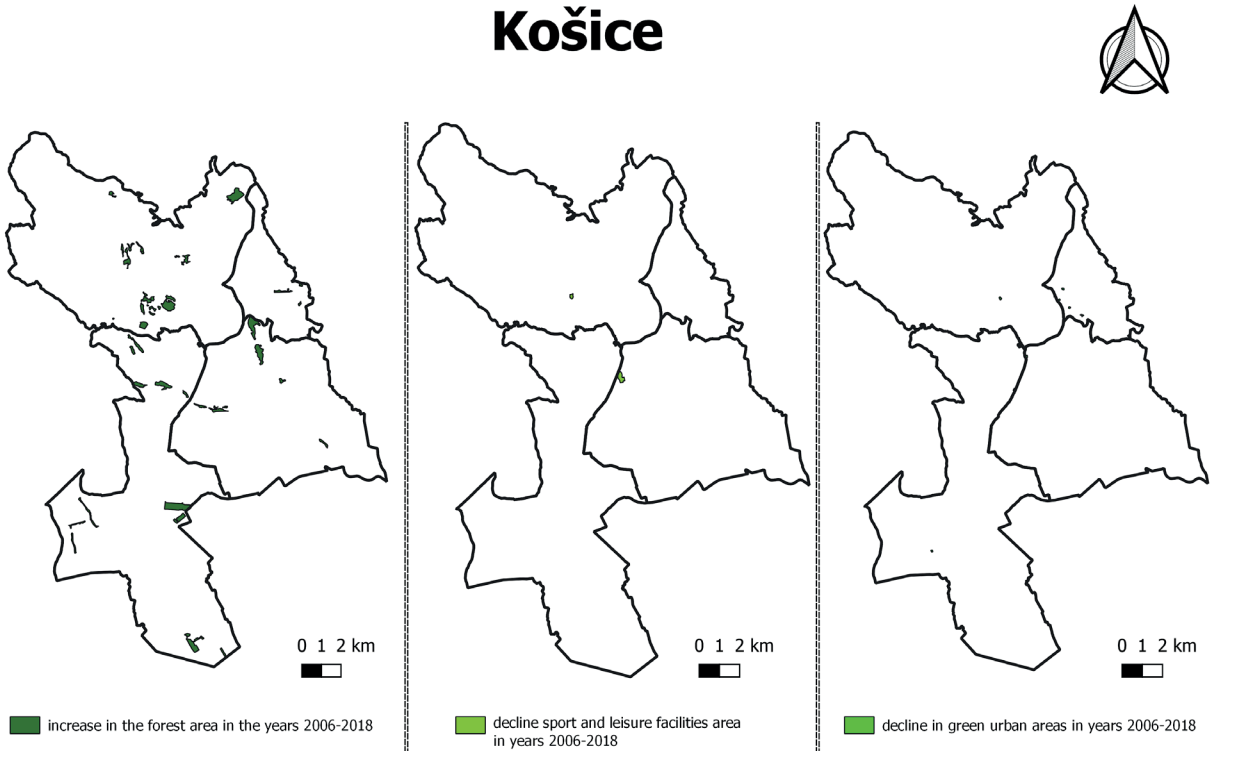


Fig. 2. Changes in green spaces in Košice
Source: own preparation.

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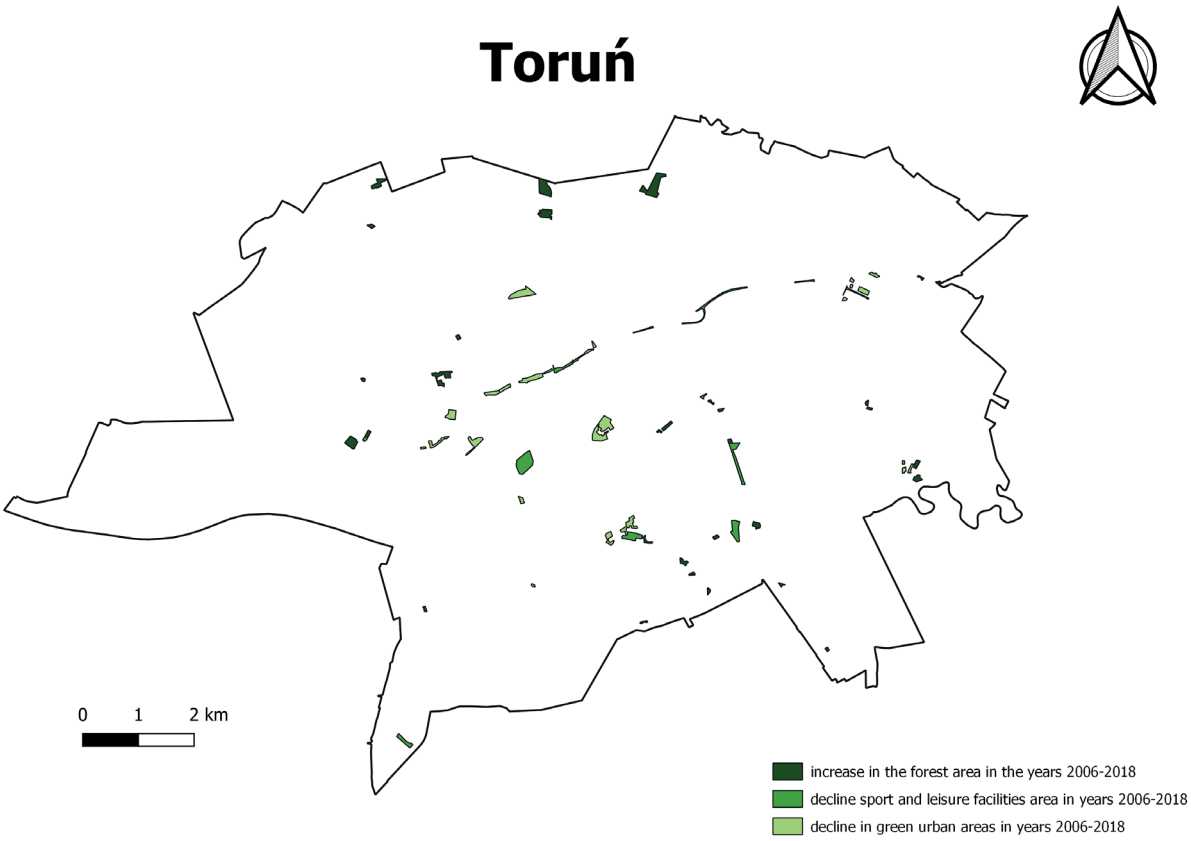


Fig. 3. Changes in the area of green spaces in Toruń
Source: own preparation.

was a decrease in green urban areas and sport and leisure facilities.

In the case of Toruń, spatial regularities in the changes in the area of green spaces were noticeable. As can be seen from the analysis of data in Toruń, the area of green urban areas decreased by almost 30 hectares. When analysing the prepared map bases with changes in the area of green spaces, a linear pattern of changes in the area of green urban areas can be seen (cf. Fig. 3).The authors decided on a different graphic presentation of the changes in the figures, so as to emphasize the relationships between linear changes in Toruń and random changes in Košice. In addition, the changes to the green urban areas and sports and recreation areas were small and hardly noticeable in one graphic.

The linear pattern of changes on the east-west line is due to the investment in road infrastructure in Toruń. The remaining changes in the area of green urban spaces in Toruń are of a dispersed character, without a clear pattern. Below, the figure shows new forest areas and areas where green urban areas and sports and leisure facilities have been replaced by another category of land cover.

To sum up, a negative balance of green spaces was recorded in Toruń and Košice. In the case of both cities, there is a noticeable increase in the area of forest areas, which is related to the natural forest succession. Moreover, in the case of Košice, spatial changes in green spaces are random, while in Toruń the changes are mainly linear.

Block II: Green space transformations

In 2012, there were 30 areas in Košice where the land cover changed into areas other than green spaces. In total, this change covered an area of 30.22 ha.

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This area was the starting area (2006) in relation to the calculation of changes in land cover in 2012.

In the years 2006–2012 in Košice, the first dominant change in green areas was the creation of non-specific areas (38%). The second dominant direction of changes was the creation of areas classified as industrial, commercial, public, military and private units on green spaces (26%). In the third place, in the years 2006–2012, mineral extraction and dump sites were created on green spaces (15%). The remaining changes in the purpose of urban green areas were of a marginal nature, i.e. they covered less than 10% of the total green areas. This fact, near the city's surface, is an almost imperceptible value. In 2006–2012, the creation of new green spaces was incidental and included the creation of new green spaces with an area of 6.84 ha, mainly in semi-natural areas.

In the years 2012–2018 in Košice, a significantly lower dynamics of changes in the creation of new areas in green spaces is noticeable. In the analyzed period, 12.51 ha of green spaces changed their purpose. The main direction of changes in 2012–2018 was the creation of new mining areas and landfills in green spaces (38%). Secondly, as in 2006–2012, industrial and commercial areas were created in green spaces (29%). It is important to underline the fact that in the years 2012–2018 green areas were more intensively transformed into the urban tissue. In total, these changes covered 4.06 ha, which accounted for 32% of all changes. The creation of new green spaces in 2012–2018 also had a small share. During this period, only 3.44 ha of new green spaces were created.

In Toruń in 2006–2012 59.43 ha of land classified as green spaces in 2006 underwent transformation. It is almost twice the changes in Košice, so the intensity of changes in Toruń is definitely greater. The main direction of transformations of green spaces in Toruń in 2006–2012 was the creation of new construction sites. It was they that occupied the largest area of green spaces (36%). As in Košice, industrial and service areas

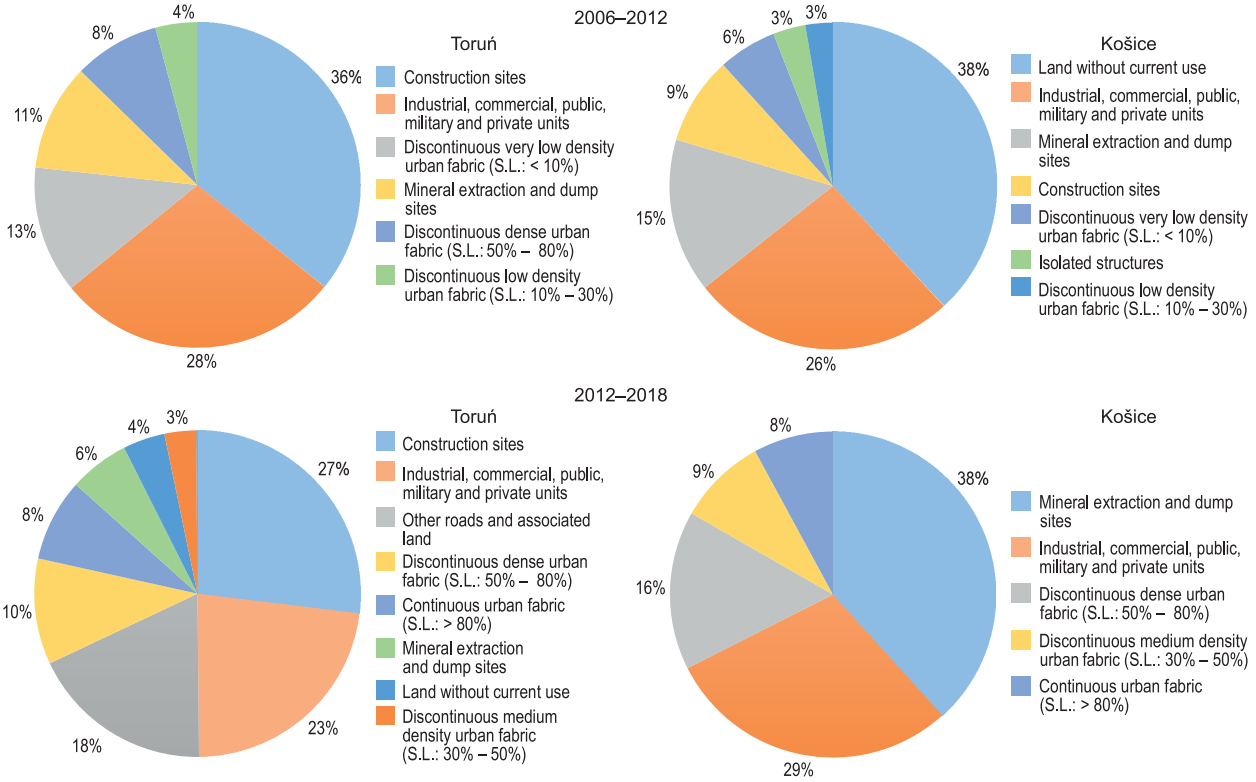


Fig. 4. The share of land developed in green spaces in 2006–2018 in Košice and Toruń
Source: own preparation.

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were built second to green spaces (28%). A share of more than 10% of changes was also recorded in areas with low intensity of urban tissue (13%) as well as areas of landfills and mining (11%). The remaining land cover categories converted to a low degree from green spaces. In the years 2006–2012, 20.04 ha of new green spaces were created in Toruń, which were mainly created in semi-natural areas (89.86%).

In Toruń, in 2012–2018, half of the transformation of green spaces into other areas involved the creation of construction sites as well as industrial and commercial sites (27% and 23%, respectively). A large share (18%) is also the creation of new roads in green spaces, which was indicated in the first block of the results. Compared to Košice in Toruń in 2012–2018, the share of land creation with urban tissue in green spaces is smaller and amounts to 21% in total.

In 2012–2018, the creation of new green spaces did not achieve a high result. In the given period, only 6.75 ha of new green spaces were created. These areas were created from various areas, incl. pastures, storage and industrial areas.

The categories of areas that arose from green areas in the analyzed period in both cities are very diverse. There is no one dominant direction for transforming green areas into another. In both cities, it is possible to point out that the green areas were transformed into industrial areas. However, in Toruń, in the years 2012–2018, a large percentage of green areas was designated for transport areas (roads), which can be seen in the linear system of changes in the area of green areas (Fig. 4).

Block III: CES analysis

The most significant regions of ecological problems are regions with unfavorable ecological conditions (Bratislava area, Košice basin, etc.) and then they are regions (territorial blocks) of ecological stability (eg Brezno, Malé Karpaty, Tokajské vrchy, etc.) (Reháčková & Pauditšová, 2007).

The following unstable landscape elements are in the cadaster of the municipality of Košice district Košice I. CES = The value of CES according to the Míchal methodology in the cadaster of the Košice I. is 3.006, which is assessed as a natural and nature-friendly landscape. There is a significant predominance of ecologically stable structures. In this, let us notice especially the high share of woodland and permanent grassland, occupying almost 6 million m^2 of the total area of the examined cadastral area. Ecologically unstable structures included urban areas to the extent of 1 822 000, i.e., built-up areas. According to Michal, we calculate the CES = 3.006. The following stable and unstable landscape elements are in the cadaster of the municipality of Toruń. CES = 2.648.

The following unstable landscape elements in the cadaster of the municipality of Toruń are quite balanced landscapes, in which the technical objects are relatively in accordance with the preserved natural structures, the result is a lower need for energy-intensive deposits. The value of CES according to the Míchal methodology in the cadaster of the Toruń is assessed as a quite balanced landscape.

It is clear from the results of CES that the city of Košice I. shows values close to natural structures, as stable elements prevail over unstable ones. The city of Torun is similar, but it is defined in the second category as quite balanced landscapes. Following the results of the research carried out in the previous sections, this article also confirmed the fact of an increase in green space in both cities, but in the case of the city of Toruń, this decrease is much more pronounced. This fact is also visible in the result of the CES calculation within the analysed cities, when the city of Košice shows results closer to the natural structures of the area. Another fact that was confirmed to us in the CES calculation is that the only component of greenery that increased its area was forests. In both analysed cities, the area of forests increased, while in Košice there were more than twice as many forests as in Toruń. When analysing the spatial distribution of changes in the surveyed cities, it is necessary to point out that in the case of the analysed area of Košice I., these changes were concentrated in the northern and central part of the city and mainly concerned the creation of new forest areas. In the coming years, attention will need to be paid to the transformation to green spaces in cities. As a result of the constantly increasing urbanisation in both Slovakia and Poland, the population in cities

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Table 5. The value of CES according to the Miklós methodology in the cadastre of the municipality of Košice I. and Toruń

City	Landscape elements km^2					
	Field	Meadows	Gardens	Forests, water, wetlands	Others	Total CES
Toruň	5,18	0,00	3,59	44,86	0,31	0,89789
Košice	0,001504	0,0054	0.391	0,071154	0,000759	0.57288

Source: own preparation.

is expected to double almost twice. The problems in connection with the growing development in cities and the loss of green areas are already evident today, as evidenced by the results of research and statistics from European Healthy Cities Network 2022. Instead of new construction on a green field, the solution within the housing policy can be, for example, the use of old buildings, factories in short, brownfields for these purposes. However, the disadvantage of this solution is the high initial financial costs, which discourages potential investors and the city from making effective use of these spatial aspects of the territory (Míchal, 1985; Miklos, 1986; National Network of Healthy Cities CR, 2022).

Another possible tool that many European cities are starting to use is parking spaces in central parts of cities. These concrete areas are available for the conversion of green areas as part of the displacement of passenger car traffic. Parking houses, on the other hand, serve as points of reference for possible parking on the outskirts of the city, while residents can then get to the city centre via ecological public transport, on shared bicycles or on foot. This concept has been introduced in many cities by, for example, the Netherlands, Belgium, Italy, Norway, Denmark, etc. (National Network of Healthy Cities CR, 2022). In our opinion, this concept within the possible transformation of green spaces in the central parts of the analysed cities would be a suitable way to increase this number of green spaces in the centre of the analysed cities in Poland and Slovakia.

The value of CES according to the Miklós methodology in the cadastre of the municipality of Košice I. is 0.57288 = the area is moderately stable. The value of CES according to the Miklós methodology in the cadastre of the municipality of Toruń is 0,89789 = the area is moderately stable. Košice and Toruń are characterised by good ecological resilience, but the larger forest area in Košice has a positive effect on the CES value. It is therefore necessary to use tools and resources to introduce protective measures in the city's landscaped area and to support the recultivation of the area.

DISCUSSION

As Jirout (2016) and his team point out, the growth of forest areas within the city space is an important element in creating ecological stability. This is confirmed by the research carried out, which clearly shows the increase in forest area in Toruń and Košice in 2006–2018 and the positive value of the CES index. According to Vyleta (2019), in order to maintain the high ecological stability of the urban landscape, it is necessary to prefer spatial development that takes into account the growth of ecologically stable areas, such as green spaces. Such planning primarily respects the assumptions of the sustainable city (DeFries et al., 2007), retains the shape and character of the cultural landscape (Mörtberg et al., 2007) and meets the requirements of the inhabitants (Miller & Hobbs, 2002), which will also translate into the overall ecological stability of the city and landscape. The ecological stability of the city's landscape, apart from the ratio of stable to unstable elements, is influenced by their fragmentation.

Tárníková and Muchová (2018) indicates that the high fragmentation of ecologically stable areas negatively affects the ecological stability of the entire urban system. In the context of this study, it can be concluded that the changes taking place in the green spaces in Košice and Toruń are highly fragmented. Thus, they negatively affect the ecological stability of the city's landscape. On the other hand, Gałaś and Gałaś (2009), when examining ecological resistance, believes that the very idea of ecological stability

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of a landscape assumes that with an increase in both the area share of stable elements, the area becomes more ecologically stable. By being stable, it is more resistant to various types of anthropopressure that destabilize the ecological resilience of the landscape. In the case of Toruń, we can clearly see that strong anthropopressure (creation of a cross-diameter route) expressed in a linear decline in green spaces contributed to a decrease in the CES index in the city. The city, keeping the green spaces in this place, would increase its ecological stability. However, the dynamic development and the pressure to modernize the city's transport network led to the loss of green spaces, which are valuable from the point of view of ecological stability.

According to research by Hruška and Petrovič (2018), ecological stability appreciates forest and semi-natural areas. In 2006–2018, over 320 ha of land classified as forests by the Urban Atlas were added to Košice. This undoubtedly contributed to an increase in the ecological stability of the city's landscape. However, such changes may be associated with a change in land cover categories, and not with the creation of special new forest areas. It is important to underline the fact that changes in the area of creating new forest areas occupy a large area, and therefore their impact on ecological stability will be much greater than in the case of fragmentary changes in Toruń.

CONCLUSIONS AND SUMMARY

As shown by the research, increasing the area of green spaces has a positive effect on the development of ecological resilience. It is refreshing that both cities increase the area of green spaces by increasing the area of forests. The creation of new GUA and sport and leisure facilities would also have a positive impact on ecological resistance, however, in the limited space of the city, the process of creating these areas is difficult.

In the analyzed period, there was an increase in the area of green areas in both cities. This increase was definitely influenced by the increased forest succession, as the largest number of these areas was increased. In Toruń and Košice, a downward trend in the construction of new green urban areas and sports and recreation areas is noticeable. The main direction of the transformation of green areas in Košice is the creation of new warehouse space in green areas, while in Toruń, green areas mainly include areas related to the creation of new industrial or commercial areas. It is disturbing that the creation of new green areas in Košice and Toruń is negligible. Košice and Toruń are characterized by good ecological resistance, but a larger forest area in Košice has a positive effect on the CES value.

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ARTICLE

Green spaces in Polish large prefabricated housing estates developed in the socialist era

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Abstract

Green spaces are an important element of the spatial structure in large prefabricated housing estates. They have their strengths and weaknesses and generate a number of opportunities and threats, the identification of which allows the potential of these areas to be realised and further developed. The goal of the study is to present the general condition and future of green spaces in large prefabricated housing estates in Poland. It is important to note that to date no research works have been published in the literature that would investigate green spaces in such estates using the SWOT/TOWS method, as confirmed by a search of the Web of Science and Scopus databases. The study area included two such estates located in two Polish cities: Toruń (Rubinkowo I) and Kraków (Bronowice Nowe). The study used the SWOT/TOWS method and an urban-architectural inventory research walk. The results of the study indicate that the best strategy for developing green spaces in estates of this kind is the competitive strategy, which involves taking advantage of opportunities while reducing the weaknesses of green spaces. The research walk also identified a diverse composition of green space species and a high proportion of green spaces in the overall estate area. In addition, green spaces are socially inclusive and can be an important element of urban resilience. The results of this research contribute to the discussion on the condition and future of green spaces in the estates.

Keywords Green areas · Green resilience · Multi-family housing · Social integration · Urban policy

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1 Introduction

1.1 Large prefabricated housing estates in Europe and Poland

The large prefabricated housing estates created in European cities after the Second World War were a response to the existing housing deficit caused by, among other things, warfare and the growing baby boom (Chmielewski, 2001; Hess et al., 2018; Tofiluk et al., 2019). Pioneering buildings and entire large-scale developments were built in the Netherlands as early as the 1930s. There are also well-known examples from Western and Northern Europe, including Germany (e.g. Gropiusstadt in Berlin), Finland, France, Sweden, or the UK. The construction of the estates to meet housing demand was also a feature of urban development in European post-socialist countries during the second half of the 20th century (Hess & Tammaru, 2019). Estates of this type are found, for example, in Hungary (Losonczy et al., 2020), Slovakia (Kristianova, 2016), the Czech Republic (Tanaka, 2019), Latvia (Treija et al., 2012), Romania (Marin et al., 2023), Lithuania, and Estonia (Pirrus & Leetmaa, 2023), Croatia (Svirčić Gotovac, 2023), and also in Poland (Dawidowicz & Dudzińska, 2022). They were often planned as part of a larger neighbourhood. For example, Marin et al. (2023) indicate that around two-thirds of Bucharest's approximately 2 million inhabitants live in such estates. In Poland, the first building of this type was a block of flats in the Jelonki housing estate in Warsaw, built in 1957 (Gronostajska, 2007). The authors consider large prefabricated housing estates to be large-scale urban developments that incorporate both the apartment blocks themselves and the accompanying infrastructure in their morphology. Such developments cover a large area and are an important part of the city's housing stock (Benkő, 2015; Škorić & Krklješ, 2019). Moreover, the name of large prefabricated housing estates comes from the technology used in their construction – prefabricated reinforced concrete panels with a width and height of several metres (Wardach & Krentowski, 2023).

The period of post-war reconstruction in Poland was the time of the second industrial revolution, involving the introduction of automated production systems and numerical techniques that greatly facilitated production, including construction. Therefore, the 1950s and the following years were an era of fast and modular construction of low architectural and aesthetic quality (Szafrańska, 2015; Trzcinska, 2021). This was characteristic of many urban centres in Poland (e.g. the Za Żelazna Bramą estate in Warsaw, Toruń's Rubinkowo, the Gądów Mały estate in Wrocław, Poznań's Rataje — cf. Table 1), which, in their initial phase, were often devoid of service facilities and green areas. However, these shortcomings were gradually overcome. It was also a time of rapidly filling the post-war housing gap and responding to the baby boom of socialist Poland. It is worth noting that during this period an average of up to 220,000 dwellings were built annually; the highest number of dwellings was built between 1971 and 1979 — as many as 260,000 per year (Jarmuż, 2020). State investment for the expansion of energy, telecommunications, and transport infrastructure was also of great importance for the rapid growth of the estates (Koryś &Tymiński, 2021). Today, they are an integral part of the landscape of most Polish cities (see Table 1) constituting a significant part of the housing stock in large urban centres (Gorczyca et al., 2020; Hess & Tammaru, 2019).

There are many arguments in the literature pointing out the advantages and disadvantages of the estates. Similarly, among the residents of these estates, there are both supporters and opponents of this type of development. Kolisz et al. (2015) points out that '*critics*

Table 1 Examples of large prefabricated housing estates in Polish cities based on a literature review

No.	City	Example of a large prefabricated housing estate	Reference
1.	Wrocław	Popowice, Huby, Polanka	(Gronostajska, 2010)
2.	Bydgoszcz	Kapuściska, Wyżyny	(Michniewicz-Ankierszta-jn, 2013)
3.	Toruń	Rubinkowo I, Rubinkowo II, na Skarpie	(Knieć, 2020)
4.	Lublin	os. XXX-lecia, os. 40-lecia, os. im. St. Moniuszki	(Ostanska, 2009)
5.	Gorzów Wielkopolski	Piaski, Staszica	(Rymar, 2005)
6.	Zielona Góra	Pomorskie	(Alsabry et al., 2016)
7.	Łódź	Manhattan, Retkinia	(Sowińska-Heim, 2014)
8.	Kraków	Bronowice Nowe, Ruczaj-Zaborze, Albertyńskie	(Kolisz et al., 2015)
9.	Warsaw	Za żelazną bramą, Tarchomin, Stegny	(Szynkarczuk, 2015)
10.	Opole	im. Armii Krajowej, Chabry	(Dembicka-Niemiec, 2014)
11.	Rzeszów	New Town	(Moskal, 2015)
12.	Białystok	Bojary-Piasta, Piaski, Zielone Wzgórza	(Kłopotowski, 2009)
13.	Gdańsk	Zaspa, Przymorze	(Tomaszewska, 2017)
14.	Katowice	Tysiąclecia, Kokociniec, Staszica	(Chmielewska, 2009)
15.	Kielce	Ślichowice, Herby, Chęcińskie	(Mochocka, 2019)
16.	Olsztyn	Jaroty, Pieczewo	(Dawidowicz & Dudzińska, 2022)
17.	Poznań	Rataje, Winogrady	(Kanoniczak, 2018)
18.	Szczecin	Kaliny, Przyjaźń	(Wojtkun, 2011)

Source: own elaboration

often forget how disadvantaged housing conditions were before the advent of prefabricated technology.' The main problem of the estates is their failure to meet current housing standards and user requirements (Vila-Vázquez & Petsimeris, 2023). In Poland, most efforts to improve the functionality and image of such estates are limited to insulating the buildings and providing a colourful façade (Kolisz et al., 2015). Nevertheless, a comparative analysis of large prefabricated housing estates and those built right after the Second World War by Sendi and Kerbler (2021) in Slovenia shows that the advantages of the prefabricated estates include: more space between neighbouring buildings, the provision of basic social and commercial services in close proximity, or relatively many enclaves of greenery and places for recreation.

1.2 Role of green spaces in large prefabricated housing estates

In the Polish legal system, there is a definition that comprehensively describes green spaces. They are understood as arranged areas with technical infrastructure and buildings, covered with vegetation, performing public functions. These include, but are not limited to, parks, greens, greenery accompanying buildings, including the greenery of residential areas (Act, 2004).

Green spaces in the literature are classified by accessibility, function, and method of arrangement. Accessibility is broken down to: full, limited, and no access (or with the owner's permission). The functions of green spaces can be divided into: separating, isolating, recreational and leisure, accompanying, and related to agricultural production. Arrangement types are as follows: designed areas, areas developed with public participation, areas

developed as a result of arbitrary investment, areas left undeveloped ('fourth nature') (Klopotowski, 2016; Giannico et al., 2021). Furthermore, green spaces are divided into high, medium, and low vegetation. It is an element of urban space consciously composed (Piatkowska, 1983), separated, and shaped according to the development plans of cities and settlements (Bartosiewicz, & Brzywczy-Kunińska, 1983). Other typologies are based on criteria such as size hierarchy or spatial scale (e.g. corner park, pocket park, regional park), institution responsible for management (e.g. national park, city park), degree of naturalness or plant form and origin as dominant features (e.g. grassland, woodland, shrubland) (Ignatieva & Mofrad, 2023; Braquinho et al., 2015; Peña-Salmón et al., 2014).

When analysing green spaces in the city, it is also important to mention green infrastructure, which is closely related to green spaces (Monteiro et al., 2020). Green infrastructure in a city is a network of natural and semi-natural areas and technical elements (Meerow, 2020) that are designed and managed to provide a variety of ecological, social, and economic benefits (Pauleit et al., 2021). It includes green spaces such as parks, gardens, squares, green roofs and walls, but also water systems such as rivers, lakes, and reservoirs that are integrated into urban infrastructure (Grabowski, 2023). Based on their literature review, Bartesaghi Koc et al. (2017) distinguished four main categories of green infrastructure: (a) tree canopy, (b) green open spaces, (c) green roofs and (d) vertical greenery systems (facades/walls). They note, however, that there is no comprehensive classification of green infrastructure. The authors suggest that a ternary approach considering the functional, structural, and spatial configuration aspects of green spaces should be used to systematise green infrastructure. From the point of view of the conducted study on large prefabricated housing estates, both green areas and broadly defined urban green infrastructure are the key elements that strengthen the resilience of these areas as well as their attractiveness in the space of contemporary cities, which is highlighted in detail by Kristianova (2016).

Among the most distinctive features of a large prefabricated housing estate are the generously designed, wide open green spaces. Kristianova (2016) points out that the design of such estates was guided by modernist concepts of living in multi-storey buildings standing amidst extensive green spaces and the modernist approach to the creation of public spaces. The open spaces were designed according to the requirements of a socialist society and were well equipped with roads, car parks, pedestrian routes, waste collection areas, as well as extensive green areas with space for recreation (Kristianova, 2016). Green areas, as reported by Treija et al. (2012), were an important element of the estates, occupying 40–45% of the territory, as well as being essential for the creation of a favourable microclimate in the estate or a distinct and diverse urban landscape (Szymańska et al., 2015).

According to Mierzejewska (2004), the aesthetic aspect is one of the functions of greenery in these estates. Therefore, greenery is an element that improves the aesthetics of the urbanised landscape, and is a mandatory feature of public spaces. The biological and health value of greenery is also important, which manifests itself primarily in its ability to improve air composition by, e.g., absorbing dust. This is confirmed by a study by Suligowski and Ciupa (2023), who indicate a negative correlation between the per capita rate of green and blue areas and the average daily number of COVID-19 cases and related deaths. The plants also secrete essential oils, which have a beneficial effect on people's wellbeing. In general, communing with nature shapes one's personality and enables the establishment or deepening of interpersonal relationships (Baur & Tynon, 2010, Senetra et al., 2018). An important role of greenery in the analysed settlements is also isolation and protection (Sarı

& Bayraktar, 2023): noise attenuation, strengthening of slopes and landslides, reinforcing of soils exposed to erosion (Halecki et al., 2023; Nawar et al., 2022). Important ecological functions of greenery also include offsetting the heat island effects (Lin et al., 2023; Zhang et al., 2021) through its ability to cool the air and increase humidity (Kuchcik et al., 2016). Plants are also responsible for phytoretention, or water storage, which is particularly important during heavy rainfall (Kazak et al., 2018; Wilczyńska et al., 2021), also increasing the biodiversity of biota as they become a habitat for many species (Coolen & Meesters, 2012). Moreover, green spaces also have a social function. The social effects of green spaces in the estates are that they contribute to social integration of residents (Treija et al., 2012), bolster physical and mental health (Noszczyk et al., 2022), and improve people's lifestyles (Ihlebaek et al. 2018).

It should be remembered that properly shaped urban space should include green areas in the form of designed landscaping — 'green infrastructure' of high aesthetic and functional quality (Feltynowski, 2023). Żarska (2011) proposes that landscape ecological tracts should be created, thus ensuring ecological and functional continuity of natural areas in estates in the city (and beyond). As pointed out by Mierzejewska (2001, 2004) and other authors, these actions help restore the ecological balance, increase the aesthetic and visual qualities of the urban landscape, and thus improve the quality of people's lives. Architect Modrīte Lūse's research was interesting in this respect, as it showed that residents of settlements in the Latvian SSR were reluctant to use green spaces because of dissatisfaction with their arrangements (Treija et al., 2012). A factor that increased the time spent in green areas was the type and appearance of the greenery, particularly areas where the greenery was a mature stand of trees with large crowns providing shade (Treija et al., 2012).

1.3 Aim of the study and novelty of the research

The goal of the study is to present the general condition and future of green spaces in large prefabricated housing estates in Poland. In order to achieve it, the authors posed the following research questions:

Q1 What is the general condition of green spaces in large prefabricated housing estates in Polish cities?

Q2 What are the most important strengths and weaknesses of green spaces and the opportunities and threats facing green spaces in large prefabricated housing estates in Polish cities?

Q3 What is the most beneficial strategy for developing green spaces in large prefabricated housing estates?

The novelty of the research lies in the relatively unpopular use of the SWOT/TOWS method to present the condition of green spaces in these estates. This is confirmed by searches in two bibliometric databases, i.e., Scopus and Web of Science, covering scientific resources published since 1899. The aim of the review of databases was to find scientific articles that simultaneously contained the following search phrases in their title, keywords or abstract: green spaces, SWOT/TOWS analysis, socialism, large prefabricated housing estates

(Fig. 1). The analysis confirms that there is a research niche in the study of green spaces in large prefabricated housing estates (Fig. 1).

Source: own elaboration.

2 Materials and methods

2.1 Study area

As highlighted by Boone et al. (2012), comparative approaches need to be linked by the common denominators of the entities analysed. Therefore, the cities and estates were not selected at random. The choice was motivated by several factors. The first was the fact that Toruń and Kraków are cities of medieval origin, having a historical centre with an orthogonal street grid (Kukulska-Kozieł et al., 2019). Another reason is the presence in the spatial structure of both cities of development elements created in the socialist era, such as former industrial complexes, cross-city roads, and large prefabricated housing estates. Two estates were selected for analysis: (1) Rubinkowo I, located in the central part of Toruń, and (2) Bronowice Nowe, located in the north-western part of Kraków (Fig. 2).

The two estates share a number of common features, including that they were built in a similar period as prefabricated (large panel) housing and consist of multi-family buildings. In addition, they are characterised by a high proportion of green space in the total area of the estate (cf. Table 2).

[c] estimated using publicly available spatial data — the contours of the green areas as shown in the database of topographic objects (BDOT10k), supplemented by vectorised areas identified through orthophotomap interpretation.

2.2 Research methods

The methods used: Urban-architectural inventory research walk and SWOT/TOWS analysis are triangulated. The aim of the authors was to obtain results using two different methods – to look from different perspectives, rather than to propose one new combined tool or method. Triangulation can be used to deepen research and, in particular, to increase knowl-

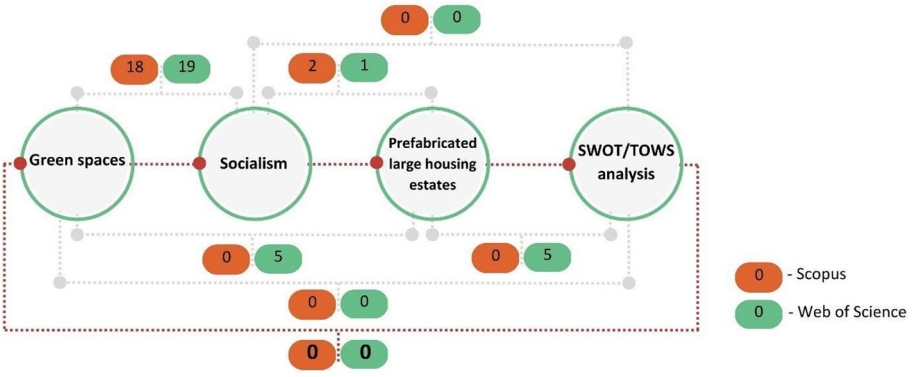


Fig. 1 Bibliometric analysis in Scopus and Web of Science databases (as of 18 July 2023)

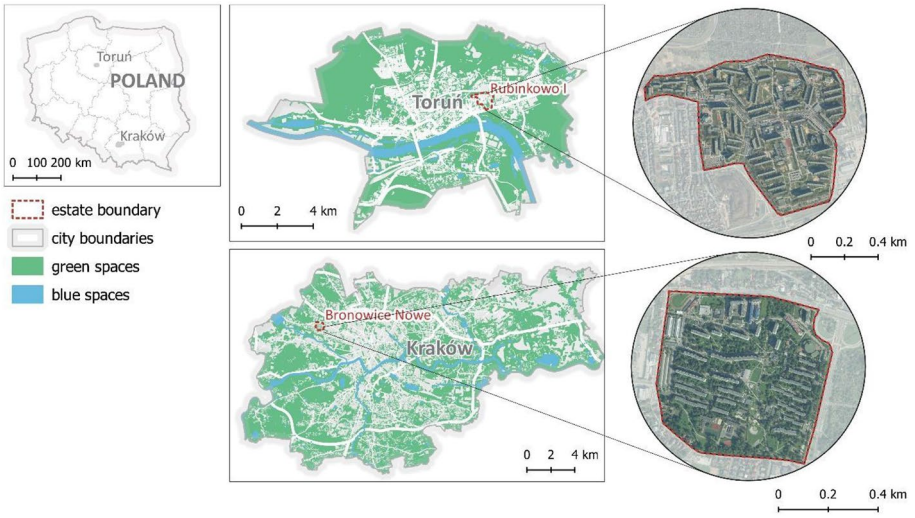


Fig. 2 Study area. Source: own compilation based on BDOT10k and ortophotomaps
Source: own elaboration

Table 2 Characteristics of the studied estates in Toruń and Kraków

Feature	Toruń, Rubinkowo I	Kraków, Bronowice Nowe
Time of construction	1970s	1970s
Origins	housing estate for employees of the Elana polyester fibre plant	estates for employees working in public administration facilities (e.g. Institute of Physics)
Area (ha)[a]	59	40
Number of inhabitants [b]	approximately 10,000	approximately 7,000
Main road serving the study area	Szosa Lubicka (national road No. 80)	Armii Krajowej (district road 2201 K)
nature of the development	multi-family residential	multi-family residential
construction technology	prefabricated construction	prefabricated construction
share of green areas in the estate[c]	57%	50%

Source: own elaboration

[a] obtained by vectorisation of the orthophotomaps

[b] data obtained from the housing cooperatives Rubinkowo in Toruń and Widok in Kraków

edge of the context of the phenomenon under study and allows the objective of the study to be achieved (Denzin, 1978).

2.2.1 Urban-architectural inventory research walk

The use of walking as a research practice has been used for a long time (Kinney, 2017). The urban-architectural inventory research walk allows mapping and learning about specific places and different aspects of space. It is a method derived from ethnographic research and falls into the category of 'research in action'. Many advantages of this method are pointed

out in the literature. For instance, it is emphasised that during the walk, data are not only recorded with a camera, but also by the body of the researcher, who, while moving through the space, experiences it with multiple senses (Gierczyk & Dobosz, 2016; Dihingia et al., 2022). In addition, the active role of the studied place itself is pointed out, as it further stimulates the researcher (Martini, 2020). It is recommended that between two and eight people participate in the walk. The research walk also allows us to see what is difficult or impossible to verbalise and provides an opportunity to go beyond the traditional form of scientific expression — the written word (Nóżka & Martini, 2015; Brzeziński, 2019, Kowalewski & Bartłomiejski, 2020). Finlay and Bowman (2017) point out that research using walking mobilities has been increasing in recent years. During the work on the urban-architectural inventory research walk, the authors followed six subsequent stages: (1) Defining the purpose of the walk; (2) Choosing the walking route; (3) Carrying out a trial walk (under laboratory conditions); (4) Adjusting the walking route (if needed); (5) Carrying out the walk; (6) Developing and analysing results.

In the study areas (i.e. Rubinkowo I in Toruń and Bronowice Nowe in Kraków), 60-minute urban-architectural research walks of an inventory nature were carried out three times (April, June, July 2023). The field meeting was conducted according to a pre-prepared scenario, which included a set route for the walk and the elements the researchers should pay attention to. Such elements included: typical buildings, the entrance gate, characteristic greenery, the predominant type of pathway surface, street furniture elements, infrastructure for children and adults, places for social integration, residents' initiatives, investment pressure, and devastation of greenery. The aim of the walks was to identify the study area to determine the strengths, weaknesses, opportunities, and threats of green spaces. Both in Toruń and Kraków, five people took part in the research walks.

2.2.2 SWOT/TOWS analysis

In order to gain a full understanding of the condition of green spaces in large prefabricated housing estates in Polish cities, the authors conducted a SWOT/TOWS analysis, which is a comprehensive research method that includes an examination of the interior of the object of study as well as of the external environment. It consists of identifying the most important opportunities and threats as well as strengths and weaknesses derived from the endogenous conditions of the subject of the research (Tylińska, 2005). The SWOT/TOWS method is a widely used research tool that, due to its versatility, allows research to be conducted in many fields and disciplines (Ghazinoory et al., 2011). This is confirmed by data from the Web of Sciences which yielded 2207 articles between 2020 and 2023 presenting the use of SWOT/TOWS analysis in hydrology, strategic planning, environmental management, or construction, among other fields.

The SWOT/TOWS analysis is based on five stages, each stage being equally important (Helms & Nixon, 2010; Leigh, 2009). Stage one involves researchers identifying the strengths, weaknesses, opportunities, and threats of the phenomenon or topic under study. This is a vital step in the method described, as it determines the rest of the procedure (Obłój, 2010). In this step, the key areas of operation and the most salient features of the object of study should be selected. In the second stage, the researcher should select and weigh the most important opportunities, threats, strengths, and weaknesses from the point of view of the research carried out. An arbitrary method is mainly used to determine the weights of the

various characteristics, but in order to maintain the objectivity of the research conducted, the authors decided to choose the method of competent judges. It is a method in which the evaluation of research material is carried out by an odd number of independent experts in a given field, who evaluate the material without communicating with each other (Włodarczak, 2006). Most importantly, the weights given to the features in each of the four parts of the analysis should add up to 1. In stage three, cross-tabulations should be made comparing all the characteristics analysed with each other. The interior of the cross-tabulations contains an indication of the interaction between the characteristics under study (1 = interaction present, 0 = no interaction). Subsequently, the SWOT/TOWS investigator determines the number of interactions in each table and multiplies the predetermined weights by the sum of the interactions. The final action in step three is to determine the sum of the products. Stage four is based on the aggregation of the results which have been prepared in the form of cross-tabulations. In stage five, the aggregated data are transferred to a matrix of strategies, from which it is possible to indicate which one is the most appropriate in terms of the phenomenon under study. As a result of the SWOT/TOWS procedure, the optimum strategy for the development of green spaces in selected large prefabricated housing estates in Toruń and Kraków was identified. The authors performed a summative SWOT/TOWS analysis because, in order to show a holistic approach to the development strategy of green spaces in large prefabricated housing estates, it is necessary to build on internal elements, i.e. strengths and weaknesses, analysed by the SWOT method, and external elements (opportunities and threats), which are relevant in the TOWS method (Escalona et al., 2022).

3 Results

3.1 Results of the urban-architectural inventory research walk

The urban-architectural research walk, whose route is shown in Fig. 3, resulted in an inventory of pre-established elements that researchers were to pay attention to in both large-scale housing estates. Eleven elements were analysed according to a pre-approved walk scenario.

It should be noted that both large prefabricated housing estates are dominated by multi-family housing, i.e., high-rise (e.g. 11-storey) and low-rise (e.g. 5-storey) bocks of flats (Fig. 3A). The entrance gate to both estates is a natural place for residents to enter the estate, often from public transport stops (Fig. 3B). It also has numerous retail and service outlets. It is worth noting that the housing estates analysed are not fenced and there are many elements of street furniture (including benches, litter bins, and lamp posts, Fig. 3E) or infrastructure for children (such as well-equipped playgrounds, playing fields, or skate parks, Fig. 3F) and adults (including an outdoor gym, chess tables, Fig. 3G). These elements foster integration, e.g. residents can play chess or relax on deckchairs among the greenery (Fig. 3G). They also undertake various community initiatives, such as growing plants in pots or mini gardens in front of blocks of flats (Fig. 3H) or making bird feeders.

The predominant surface of the pathways is cobblestone, which is used for most pavements, asphalt for access roads (Fig. 3D), and openwork or hexagonal cobblestone, which is used to cover the housing estate's car parks. There are definitely more such car parks in the Toruń housing estate, while in Kraków there are too few of them in relation to the needs

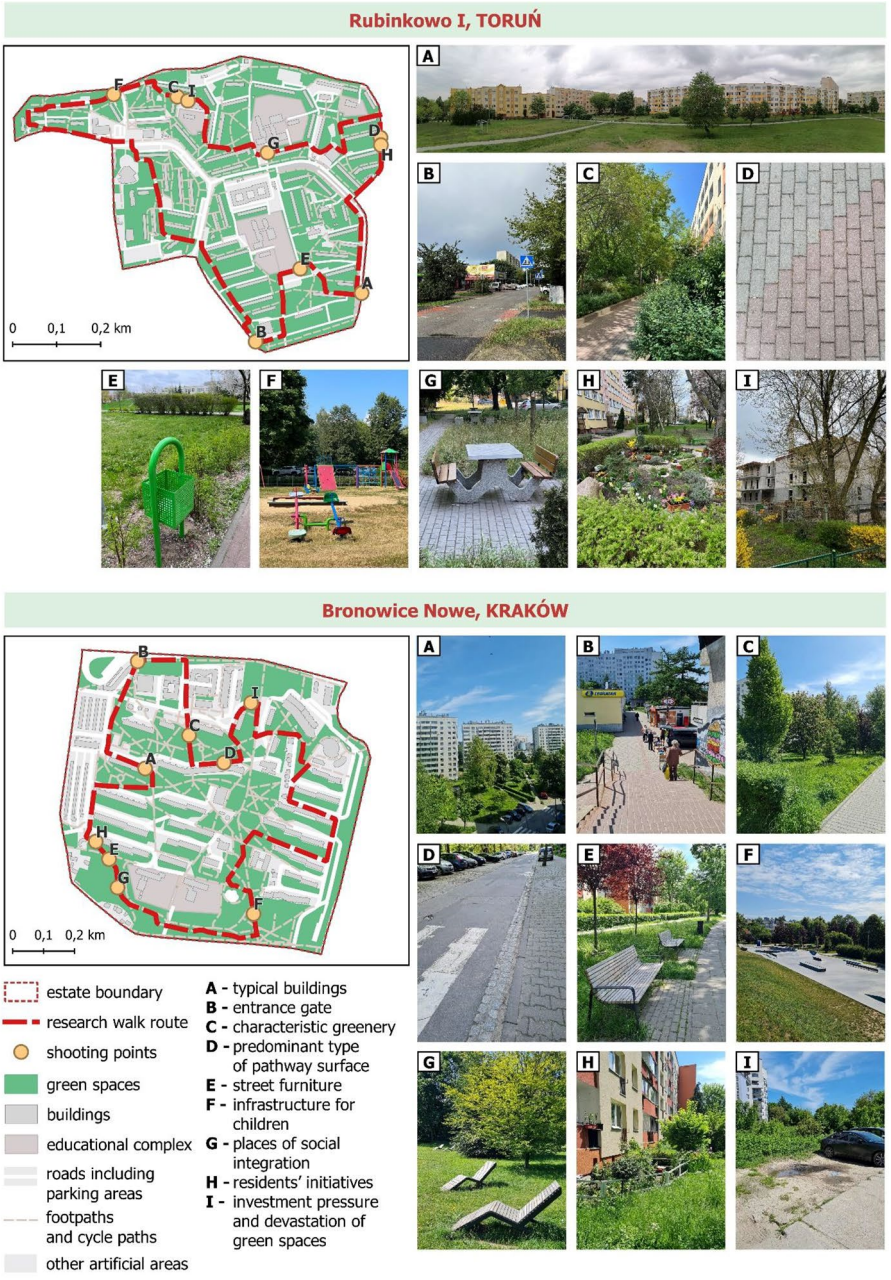


Fig. 3 Walking route with identified distinctive elements of large-panel housing estates
Source: own elaboration

of the residents, hence the noticeable devastation of green spaces by parking cars in green areas (Fig. 3I).

A characteristic feature of the estates surveyed is also the large amount of estate greenery. Mostly it is low greenery, especially lawns, shrubs, flowerbeds, but there is also a numerous and species-diverse stand of trees with a stable age structure, including both deciduous and coniferous trees (Fig. 3C). A noticeable phenomenon is also the investment pressure occurring at the expense of existing green spaces. For example, a new multi-family building is being constructed in the housing estate in Toruń, and a new kindergarten has been built in Kraków, whose design destroys the spatial order as it does not fit in with its surroundings (Fig. 3I).

3.2 SWOT/TOWS analysis results

In accordance with the procedure described in Sect. 2.2.2. SWOT/TOWS analysis, the authors first proceeded to identify the strengths (S) and weaknesses (W) as well as the opportunities (O) and threats (T) of green spaces in a large prefabricated housing estate. Table 3 presents the factors analysed with their corresponding weights.

The next step in proceeding with the SWOT/TOWS method was to establish the interrelationships between the factors indicated in the table, put them together and analyse the

Table 3 Factors subject to SWOT/TOWS analysis

No.	Weight	Endogenous factors	No.	Weight	Exogenous factors
	1.00	Strengths		1.00	Opportunities
S1	0.30	favourable microclimate supporting local and supra-local urban resilience	O1	0.34	opportunities for social integration and the development of bottom-up initiatives
S2	0.28	high accessibility of green areas for residents/users	O2	0.24	the possibility of developing small urban retention by locating water reservoirs as rain gardens
S3	0.22	providing an inclusive recreational and sporting function for various groups of residents	O3	0.22	increased public awareness of the role of green spaces in the city and new forms of greenery (pocket gardens)
S4	0.20	diverse species composition enhancing the aesthetics of the urbanised landscape	O4	0.20	the opportunity to use the potential of green spaces for positive urban branding
	1.00	Weaknesses		1.00	Threats
W1	0.34	reduction in the quality of life of users through the presence of nuisance species (e.g. allergenic, poisonous, malodorous)	T1	0.36	investment and anthropogenic pressures (e.g. building densification)
W2	0.24	poor condition of some green areas due to lack of systematic care (e.g. rejuvenation pruning, agro-technical treatments)	T2	0.26	lack of an overall design policy and coordination between bodies responsible for managing green spaces
W3	0.22	partially devastated traffic routes and street furniture	T3	0.22	devastation
W4	0.20	no connection/linkage to other green areas in the city, no continuity of green areas	T4	0.16	generation of social conflicts due to the way greenery is managed

Source: own elaboration

Table 4 Links in the SWOT and TOWS analyses

SWOT								
	S1	S2	S3	S4	W1	W2	W3	W4
O1	0	1	1	0	1	1	1	0
O2	0	0	0	0	0	1	0	0
O3	0	1	1	0	0	1	0	0
O4	0	1	1	1	0	1	1	1
T1	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	1
T3	0	0	0	0	1	1	1	0
T4	0	0	1	0	1	1	1	0
TOWS								
	O1	O2	O3	O4	T1	T2	T3	T4
S1	0	1	1	0	1	1	1	0
S2	0	0	1	0	1	1	1	0
S3	1	0	1	0	1	1	1	1
S4	0	1	1	0	1	1	1	0
W1	1	0	1	1	0	1	0	0
W2	1	1	1	1	0	1	1	1
W3	1	0	1	1	0	1	1	1
W4	0	1	1	1	0	1	0	0

Source: own elaboration

Table 5 Summary results of the SWOT/TOWS analysis

	SWOT		TOWS	
	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths/opportunities	14	3.42	14	3.42
Strengths/threats	2	0.38	26	6.74
Weaknesses/opportunities	16	4.02	26	6.42
Weaknesses/threats	14	3.2	16	3.72

Source: own elaboration

Table 6 Green spaces development strategies derived from the SWOT/TOWS analysis

	Opportunities	Threats
Strengths	Aggressive strategy	Conservative strategy
Sum of interactions	28	28
Sum of products	6.84	7.12
Weaknesses	Competitive strategy	Defensive strategy
Sum of interactions	42	30
Sum of products	10.44	6.92

Source: own elaboration

most favourable strategy. The authors used tables to present the SWOT and TOWS linkages (Table 4), the SWOT/TOWS summary (Table 5) and the strategic analysis (Table 6).

Table 4 with SWOT/TOWS linkages takes into account the occurrence of interactions between the various factors. If there is an interaction, it is indicated by '1'. Lack of interaction is presented as '0'. The summary table includes the sums of the SWOT and TOWS

relationships and the sums of the products of the weights and the interactions between the factors, which were the basis for selecting the most favourable green space development strategy in a large prefabricated housing estate (Table 5).

In the SWOT/TOWS analysis, the most appropriate development strategy is selected at the final stage (Table 6). Four strategies are possible:

- aggressive maximises the synergies between the strengths and opportunities generated by green spaces in large prefabricated housing estates (Obłój, 2007);
- conservative occurs when, with high endogenous potential, the greenery is subjected to an unfavourable set of exogenous conditions (Gierszewska & Romanowska, 2009);
- competitive, which consists of taking advantage of emerging opportunities while reducing the weaknesses of such green spaces (Filipczuk, 2008);
- defensive, where weaknesses are strongly linked to the exogenous threats to which green spaces in a large prefabricated housing estate are exposed; survival is its primary aim (Tylińska, 2005).

In the SWOT/TOWS investigation of the green spaces in the large prefabricated housing estates in Toruń and Kraków, the competitive strategy proved best for their further development (Table 6). The results obtained through the SWOT/TOWS analysis show which strategy for the development of green spaces in LHEs is most appropriate for their sustainability in the spirit of urban resilience. The identification of strategies is an extremely valuable outcome of this study. It can be used by local authorities, green management bodies or urban green NGOs.

4 Discussion

4.1 Competitive strategy for green spaces in large prefabricated housing estates

The selected competitive strategy aims to exploit emerging opportunities while reducing the weaknesses of green areas in large prefabricated housing estates.

One of the more significant opportunities offered by such areas is the possibility of social integration and the development of grassroots initiatives. Community action, a sense of empowerment and active social participation, which are the hallmarks of today's emerging civil society, will certainly help to overcome the diagnosed weaknesses. Public participation can also contribute to the elimination of the poor condition of some of the green areas or the repair of partially devastated traffic routes and street furniture. Another essential opportunity identified in this aspect is the increase in public awareness of the role of green spaces in the city and new forms of greenery.

Repeatedly addressed in the scientific discourse, the role of education (see e.g. Wolsink, 2016, McNamara et al., 2022, Biernacka et al., 2023) is a key element in changing one's attitudes and thus re-creating the space around us, including the green space of large prefabricated housing estates. Knowledge of the role of green areas in the city and an increase in public awareness of the role of green areas in the city and new forms of greenery will certainly contribute significantly to, e.g., avoiding the location of nuisance species (allergenic, poisonous, malodorous) in the vicinity of blocks of flats, which reduces the quality

of life of users of these areas (Zhao et al., 2024). If users and people responsible for the design, care, and management of green spaces in large prefabricated housing estates are provided with a certain amount of complementary, up-to-date knowledge about the care and maintenance of green spaces, it is highly likely that steps will be taken (e.g. at management level) to remedy the poor condition of some green spaces or devastated pedestrian routes. This includes knowledge of how to finance such projects, e.g. through a tool such as the participatory budget.

In the context of the negative anthropogenic changes taking place across the globe (Bowler et al., 2020; Belenok et al., 2022), including above all climate change, an important issue is the economical and rational management of rainwater, e.g. by establishing appropriate infrastructure for its retention and slow release into the environment (Oral et al., 2021). Therefore, green spaces provide an opportunity to develop small-scale urban retention by locating water reservoirs as rain gardens (Kasprzyk et al., 2022). This is a very important challenge of both local and supra-local importance as it can strengthen urban resilience. These types of solutions are systemic by design and cover significant areas of the city (e.g. streams, ponds, basins). Therefore, the development of water retention infrastructure can also help to create new or recreate formerly existing links between green spaces in socialist-era estates and other green spaces in the city (Starczewski et al., 2023a). In this way, the continuity of green corridors would be restored, which would promote the development of biodiversity so desired in the city (Halecki et al., 2023).

Positive urban branding improves the city in many dimensions (Scholvin, 2021). This fact also has its tangible, economic benefits, e.g. the development of tourism and recreation can increase municipal income. In addition, European and global cities are currently creating their branding on the basis of the green city concept or the development of green-blue infrastructure. One opportunity facing Polish cities, including Toruń and Kraków, is the possibility to use the potential of green areas in large prefabricated housing estates to shape positive urban branding. The areas analysed could have potential for the creation of new tourist attractions related to the heritage of socialism, so characteristic of Central and Eastern European cities. Their green image can encourage different forms of tourism, e.g. urban tourism. The opportunity analysed can contribute to the overall reduction of weaknesses through the systemic maintenance, nurturing, and development of green spaces.

4.2 The future of green spaces in large prefabricated housing estates

The research carried out in this article on green spaces in large prefabricated housing estates has shown that they are in line with the concepts of urban resilience, environmental justice, and the '3-30-300' principle, which are considered to be among the most important in the context of shaping green spaces in cities.

Within the framework of the present research, the concept of urban resilience is implemented in such estates through the social and environmental spheres (Kong et al., 2022). The social plane is concerned with the integration of residents, different social groups by spending time actively together in green areas (Shukla et al., 2023). During the research walk, places of social integration were identified in both Toruń and Kraków that strongly encourage the emergence of bottom-up initiatives and the establishment of relationships. In this way, social ties are strengthened, which can provide a base to be used during various crises, e.g. COVID-19 (Rajca & Kajzar, 2021). The literature suggests that green spaces also

play an important role in the process of activating seniors and improving quality of life — adding that an ageing population is a crisis phenomenon to which the development of green infrastructure may be the answer in line with urban resilience (Coetzee et al., 2016; Rogatka et al., 2021). Develop of urban resilience is furthermore manifested in the support of public health care through residents' contact with greenery (e.g. hortiterapy, sylvotherapy). The analysed green areas in the housing estates of Toruń and Kraków meet the characteristics of a resilient urban system according to Godschalk (2003), i.e. they are redundant and diverse. The area of green spaces covers more than half of the study area – meeting the conditions of redundancy. The urban walk proved that green spaces have different functions and their structure varies (presence of low, medium, and high greenery). This condition reflects the diversity of the structure. The appropriate shaping and development of urban greenery in large prefabricated housing estates enhances urban resilience, especially its social and environmental dimensions (Czachor, 2019; Starczewski et al., 2023b).

Urban resilience in its social and green dimension also fulfils the need for environmental justice. Environmental justice affirms the need to develop cities while remaining in balance with nature (Kronenberg et al., 2020; Kato-Huerta & Geneletti, 2023). This idea further emphasises that elements such as the cultural integrity of all urban communities and ensuring equitable access for all to the full range of environmental resources should be taken into account (Ramirez-Andreotta, 2019; Panikkar et al., 2023). The results of this study indicate that, undoubtedly, green spaces in large prefabricated housing estates foster social integrity through access to places that provide the conditions for this integration to develop. Carrying out documented community initiatives such as mini gardens, vegetable gardens, or bird feeders is also a testament to social concern for the quality of the surrounding space (Nowak & Siatkowski, 2022). Bearing in mind the points raised by Kronenberg et al. (2020) that in cities that have undergone a transition from socialism to capitalism little attention is paid to the context of environmental justice, green spaces in large prefabricated housing estates seem free from this problem. In addition, environmental justice is manifested here by ensuring that residents of the estates have equal and very good access to green spaces. In this way, the two estates analysed also implement the '3-30-300' principle popular in the literature, which combines visibility, availability, proximity, and accessibility to green spaces (Konijnendijk, 2023; Nieuwenhuijsen et al., 2022). According to these guidelines, every resident should be able to see a minimum of three trees from their home, place of work or study, be provided with 30% tree cover in the neighbourhood, and have a public green space within 300 m of their place of residence (Konijnendijk, 2023). The results of the urban-architectural inventory research walk carried out on the two housing estates surveyed confirmed that the greenery there is designed to meet these guidelines. Bearing in mind the above considerations and the many ecosystem benefits provided by green spaces on the one hand and uncontrolled urbanisation on the other, urban planners should draw on the good models for green space design identified in the analysed estates.

5 Conclusions

When answering the first research question (Q1), it should be stated that the identified general condition of green spaces in the large prefabricated housing estates indicates a diverse species composition and a high proportion of green space cover in the overall area of the

estates. The second research question (Q2) concerned the identification of the most important strengths, weaknesses, opportunities, and threats facing green spaces in large prefabricated housing estates in Polish cities. The results of the research indicate that the most important identified strength of green spaces is the favourable microclimate, supporting local and supra-local urban resilience, and the number one opportunity is the possibility for social integration and the development of community initiatives. The most significant weakness is the reduction in quality of life for residents through the presence of nuisance species (e.g. allergenic, poisonous, malodorous), and the most serious threat appears to take the form of investment and anthropogenic pressure. In order to answer the third research question (Q3), we should recognise that the most favourable strategy for the development of green spaces in large prefabricated housing estates is the competitive strategy which aims to take advantage of opportunities while reducing the weaknesses of green spaces.

One of the limitations of our research is the lack of opinion from the residents of the analysed estates about the overall condition of green spaces and their future in LHEs. Moreover, the definition of strengths, weaknesses, opportunities, and threats was done arbitrarily, without involving the residents of the settlements in the research process. In the future, it would be valuable to find out the perception of the local community, for example through surveys or individual in-depth interviews.

The research conducted in this article meets the need to design the green transformation of cities, and the results obtained can provide a platform for further research into new sustainable solutions for planning green spaces. Additionally, the implementation of a broadly-understood competitive green space development strategy may have a positive impact on the entire urban system.

Declarations

Conflict of interest All authors declare that they have no conflicts of interest.

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Evaluation of revitalisation projects in Poland using the Maslin Multi-Dimensional Matrix. Heading towards green & social revitalisation

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Abstract. One of the greatest challenges currently facing cities is the evaluation of the revitalisation process, i.e., verifying whether and to what extent it has been successful. This assessment is important as it will determine the extent to which the revitalisation needs of a place have been met. The aim of this article is to present the results of the evaluation of a post-revitalisation space made by its users and to determine the usefulness of the Maslin Multi-Dimensional Matrix (MMDM) method used. This is the first attempt, not previously reported in the literature, to use the MMDM for evaluating revitalisation. According to research, projects of an integration and environmental character and those improving security were the most appreciated and at the same time had the best revitalising effect on the Bydgoskie Przedmieście district in Toruń, Poland. The lowest ratings were given to infrastructural projects or those dedicated to narrow social groups (alternative arts). The MMDM method should be considered an appropriate tool for evaluating revitalisation.

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1. Introduction and research objective

The word "revitalisation" comes from Latin and means restoration to life. This means that the subject of revitalisation was in some way deprived of this "life", because of both the poor condition of spaces and buildings and an unfavourable social structure (Palicki, 2015). Over the years, many different definitions of the revitalisation process have emerged. The lack of uniformity in defining the process leads to the misuse of the word (Chmielewski, 2001; Węcławowicz, 1988). Often, the process of revitalisation is equated with renovation, i.e.: restoring the condition of a building as it existed at the beginning of the previous exploitation cycle; or modernisation, comprising renovations supplemented by the introduction of new, better, more efficient, or even additional elements of equipment that increase comfort of use (Skalski, 2006). The revitalisation process includes the above-mentioned concepts, but it is broader and, apart from technical, technological or infrastructural issues, it also refers to the social, economic and cultural spheres (Markowski et al., 2005).

The Polish literature features the principles of revitalisation systematised by J.J. Parysek (2016). The most important of these are as follows:

- Different categories of areas are and should be the subject of revitalisation;
- The revitalisation process is most often carried out by adopting a specific, general revitalisation model;
- Revitalisation is a process undertaken and implemented under the impact of: the real-estate market, economic calculation, rationally defined individual and general social benefits (not only material), and principles of social justice;
- The basic principle for undertaking and carrying out revitalisation tasks should be their social rationality, which can only be guaranteed by a well-conceived and actual socialisation of revitalisation processes (Parysek, 2016).

By distinguishing the detailed objectives and tasks of revitalisation one can see how complex the process is. Adreas Billert (2006) argued that revitalisation is also a comprehensive process of renewal of an urbanised area whose space and functions have been structurally degraded. This degradation creates a state of crisis that prevents or significantly impedes the proper economic and social development of the city in accordance with the sustainable development policy (Billert, 2006). It should be noted that, in this definition, the renewal process is directed exclusively at urbanised areas, i.e., areas that are parts of cities or post-industrial or post-military sites. In this approach, the revitalisation process excludes, e.g., rural areas, which according to the Poznań school of revitalisation are one of the subjects of revitalisation activities. Moving on, revitalisation is carried out in areas where there is degradation of elements of public space that has led to a state of crisis. It follows that the process itself cannot be carried out in areas where this state of crisis has not been diagnosed (Degen, 2017). The said degradation should include three basic elements: space, function and substance.

The literature abounds in definitions describing the revitalisation process (Table 1). They differ in content and focus on different facets of the process. Analysing the definitions quoted above and the previous considerations, an attempt can be made to synthesise these various definitions into one encompassing a range of meanings. Thus, for the purposes of the study, the following definition of the revitalisation process was adopted:

> *A system of organisational measures that are oriented towards the recovery of economic, social and infrastructural functions and bringing degraded urbanised spaces out of crisis, and directed towards the implementation of projects aimed at giving new life to urban spaces*

Morphologically, the most important element of the revitalisation process is the degraded area – a certain section of space in which negative economic, social, spatial and environmental phenomena accumulate (Rogatka, 2019). It is around the degraded area that the activities of entities and stakeholders in revitalisation are concentrated. A proper diagnosis of the degraded area is the basis for revitalisation policy (Rachwał & Świerczewska-Pietras, 2010). Revitalisation proceeds according to specific stages. The most important phases include: 1) diagnosis of the state of affairs, 2) indication of the degraded area,

Table 1. Selected definitions of revitalisation

No.	Definition
1.	"a comprehensive, coordinated, multi-annual process of spatial, technical, social, and economic transformations carried out in a specific area, initiated by a self-government (mainly local) in order to lead this area out of a **crisis state**, by giving it a new functional quality and creating conditions for its development, based on characteristic endogenous conditions" (*Guidelines of the Minister of Regional Development for programming activities concerning housing, Warsaw 2008)*
2.	a coordinated process, carried out jointly by the local government, local community, and other participants, being an element of the development policy and aimed at counteracting the **degradation of urban space**, crisis phenomena, stimulating development and qualitative changes through an increase in social and economic activity, improvement of the living environment, and protection of the national heritage, while maintaining the principles of sustainable development *(Ziobrowski, Jarczewski, 2010)*
3.	**a system of organisational**, legal and financial **activities** binding state housing policy with local housing policy of self-governments; it is a source and determinant of the improvement of housing situation of the society *(Skalski, 2000)*
4.	an integrated approach (from both the intervention and the effects side), taking into account social, economic, environmental, and technical aspects and **oriented towards functional recovery** (social revitalisation, economic revitalisation) *(Markowski, 1999)*
5.	Revitalisation refers to forms related to the age of the city, its political and economic conditions. Broadly speaking, these forms fall into four related categories: (1) catalytic – driving the process (2) inner-city – caring for urban structures, (3) neighbourhood – relating to interpersonal relationships and social capital, and (4) **project-oriented – implementing revitalisation projects**. *(Birch Oom, Beercham, 2007)*
6.	Revitalisation is the process of leading **degraded areas** out of the crisis state, carried out in a comprehensive manner through integrated actions for the benefit of the local community, space, and economy, territorially concentrated, carried out by revitalisation stakeholders on the basis of the commune revitalisation programme. *(Revitalisation Act of 9 October 2015)*

Source: own elaboration

3) social consultations, 4) enactment of the Local Revitalisation Programme, 5) implementation of projects, 6) assessment and evaluation of the process (Czyżewska, 2008). Assessment and evaluation of revitalisation have been and will continue to be a fundamental challenge for cities that have conducted a revitalisation process. Determining whether and to what extent revitalisation has been successful is a key question in planning future revitalisation work. It is necessary to determine the degree to which revitalisation needs have been met, to indicate the areas in which revitalisation has improved the spatial, social and economic condition of a given place, but also to identify those areas in which revitalisation activities should be corrected (e.g., by initiating supplementary and corrective projects) so that a comprehensive renewal of degraded areas is ultimately achieved.

The aim of this article is to present the evaluation of the post-revitalisation space by its users and to determine the usefulness of the Maslin Multi-Dimensional Matrix (MMDM) method used. Thanks to the MMDM method, it is possible to evaluate individual revitalisation projects, their usefulness and efficacy and the public demand for them. It allows for a detailed evaluation of activities through increased contact with the local community, consisting of face-to-face interviews during an MMDM workshop. The MMDM procedure guarantees the collection of detailed information, evaluations and perceptions of respondents. This method allows the researcher to have direct contact with the research group, expand their statements, clarify doubts (during the MMDM workshop), and subsequently evaluate revitalisation projects according to criteria prepared on the basis of the guidelines of the *Local Revitalisation Programme of the City of Toruń for the Years 2007–2015*. This assessment is important, as it will determine the extent to which the revitalisation needs of a given place have been met. The assessment tool that the authors will test will be the Maslin Multi-Dimensional Matrix (MMDM). This is the first attempt of its kind made by revitalisation researchers.

2. Revitalisation in Poland

After a period of intensive industrialisation and political transition, many post-industrial brownfields appeared in the country (Duží & Jakubínský, 2013). After the service sector started dominating the national economy, industrial areas or districts became problematic spaces in the urban fabric. Abandoned halls, warehouses, residential and commercial buildings began appearing in urban spaces (Soldak, 2021). It should be noted that the degradation happened not only at the technical level of the area, but also at the social level. Degraded areas suffered from more profound social problems (e.g., unemployment), were often subject to social exclusion, and the inhabitants did not feel safe there (Rogatka et al., 2021). Such spaces were naturally predestined for revitalisation.

The Polish practice of revitalisation began with the reform of the economic system from a command economy to a capitalist system. The changes in the political system in 1989 marked the informal beginning of the revitalisation policy, which steadily gained in importance in later years (Węcławowicz, 1988). Poland's accession to the European Union opened up new horizons for Polish revitalisation. Structural and pre-accession funds gave impetus to the renewal of degraded spaces in Poland (Słodczyk, 2000).

Currently in Poland, revitalisation is a common process that is based on endogenous resources (Chodkowska-Miszczuk & Szymańska, 2010). Revitalisation policy is carried out on the basis of local/communal revitalisation programmes. These are strategic documents that diagnose crisis situations in the city area. They mainly include revitalisation projects intended to bring a degraded area out of crisis. The programmes also include a financial framework for the process and monitoring methods. After Poland's accession to the European Union in 2004, European Funds provided an important impetus to carry out revitalisation projects. It was EU funds that financed most of the revitalisation projects. In order to be eligible for Community funding, Polish local authorities were obliged to draw up revitalisation programmes.

The revitalisation policy in Poland, as well as in other European Union countries, is carried out in parallel with financial perspectives that provide funds for the realisation of investments, projects and cultural events. Programming the revitalisation process within the framework of EU funds necessitates the evaluation, assessment and ongoing monitoring of these projects (Połom, 2011). Projects are often evaluated using measurable indicators specified in the applicatioFn for funding, such as number of new plantings, number of people using a park, or number of new jobs created. However, they do not always provide the actual evaluation of projects or give a picture of the post-revitalisation space, but are only a figure showing the realisation of the assumed effect (Jarczewski & Jeżak, 2010). The process of evaluating post-revitalisation spaces and the underlying projects is extremely difficult and complex due to the specificity of the process. "Hard" measures to improve the infrastructural sphere are visible to the naked eye. New façades, pavement renovation or a new square with street furniture are all tangible effects of revitalisation that are easy to assess and evaluate (Stryjakiewicz, 2002). According to the accepted definition of revitalisation, the process is to give new life to spaces, and spaces are infrastructure and people that interrelate. The evaluation of soft revitalisation measures that affect: for example, the creation of social capital, the acquisition of new skills or the formation of social ties constitute the more difficult part of the revitalisation evaluation process (Skowronek, 2014; Stawasz, 2017). The requirements of EU aid programmes stipulate that a revitalisation programme that has received financial support must be subject to ex-ante monitoring and ongoing monitoring connected with evaluation procedures (Sztando, 2008).

In order to carry out a comprehensive evaluation of the revitalisation process, it would be reasonable to supplement the above-mentioned forms based on measurable and stable indicators with the human factor in the form of an evaluation of completed revitalisation projects made by the inhabitants, i.e., project stakeholders. This would be a continuation of the participatory model used in the development of the revitalisation documents. The inclusion of such a form of project evaluation would help create a revitalisation audit that would give an overall picture of the process. If the inhabitants of the revitalised areas (who best know the problems of individual spaces) were to evaluate the completed

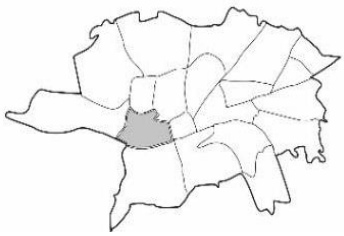
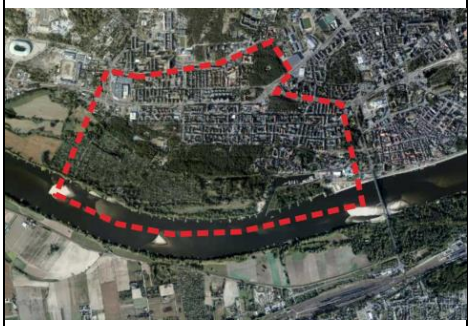
projects, it would yield measurable benefits in the form of information on whether the revitalisation carried out has met their expectations.

3. Aim of the study, temporal and spatial scope

The aim of this article is to present the evaluation of a post-revitalisation space by its users and to determine the usefulness of the Maslin Multi-Dimensional Matrix (MMDM) method used. Assessment is important as it will determine the extent to which the revitalisation needs of a place have been met. The assessment tool that the authors will test will be the Maslin Multi-Dimensional Matrix (MMDM). It should be added that this is the first attempt of this kind made by revitalisation researchers.

The analysis covers revitalisation projects implemented under the *Local Revitalisation Programme* (LRP) of the City of Toruń for the years 2007–2015. This is a comprehensive document taking into account the revitalisation needs of the city. The programme was adopted by Resolution No. 624/2009 of the Toruń City Council on 27 August 2009. The LRP was amended eight times, the latest amendment being dated 13 November 2014. The evaluation of revitalisation projects and the revitalisation process itself took place after material and financial completion of both the programme itself and the individual revitalisation projects included in it. The local revitalisation programme is one of many strategic documents created at the commune level. It is a document that in its first part undertakes an in-depth social, economic, technical, spatial-functional and environmental analysis. On the basis of the analysis, it delimits the degraded area and the revitalisation area. The forecast part of the document indicates the objectives of the revitalisation process and the method of monitoring the process itself. The LRP also includes revitalisation projects thanks to which the space designated for revitalisation is transformed from urban fallow land into a socially, spatially and investment-wise attractive area. Revitalisation projects are complemented by a detailed description of project financing. The revitalisation projects analysed were carried out an urban area of Toruń on the right bank of the Vistula River and conventionally known as the Bydgoskie Przedmieście district. In the Bydgoskie Przedmieście area, projects related to spatial and functional transformations dominated, and they were complemented by accompanying social projects. Such an arrangement in the first round of revitalisation in Poland was very common. In the Local Revitalisation Programme of the City of Toruń for the Years 2007–2015, Bydgoskie Przedmieście was identified as a degraded urban area to be revitalised (Table 2).

Table 2. Spatial scope of the study: Bydgoskie Przedmieście in Toruń

Toruń on the map of Poland	Bydgoskie Przedmieście (grey)	Bydgoskie Przedmieście on orthophotomap
		
Source: own elaboration	Source: own elaboration	Source: http://mapy.geoportal.gov.pl (DOA: 13.10.2021)

Source: own elaboration

Bydgoskie Przedmieście acquired its spatial form in the 19th century and at the beginning of the 20th century. It is from that period that the characteristic spatial layout of the district – an enclave of spatial order – originates (Rogatka & Ciesiółka, 2016). Apart from its distinctive layout, Bydgoskie Przedmieście is a space filled with extremely interesting architecture. It houses Art Nouveau and eclectic tenement houses with richly decorated fronts.

What distinguishes it from other parts of the city is its central location and its unique character, which is an architectural palimpsest: Art Nouveau, Modernism, half-timbered walls, and apartment buildings from the 20th and 21st centuries. The district was inhabited by the local elite – the intelligentsia, wealthy city-dwellers, officials who built rich villas with gardens and extensive green areas. They shaped the character of Bydgoskie Przedmieście (Rogatka, 2019; Jaroszewska-Brudnicka, 2007). After the Second World War, many of the flats were subject to obligatory rental and thus the spatial and social degradation of Bydgoskie Przedmieście began. At present, the area is struggling with many problems that are clearly defined in the Local Revitalisation Programme. In the document, the district was comprehensively diagnosed on many levels, such as poverty, social exclusion, long-term unemployment, economic activity, crime and a particularly rundown environment.

4. Maslin Multi-Dimensional Matrix method

The analysis of revitalisation transformation was based on three research stages. Stage I included literature studies – a review of the relevant literature, scientific articles by Polish and foreign authors. Stage II included the analysis of the *Local Revitalisation Programme of the City of Toruń for the Years 2007–2015*, which was the basis for further research. Stage III, the main stage of the research process, involved conducting the MMDM procedure.

The MMDM is a mathematical and statistical tool that allows for the ranking of projects not only in the revitalisation sphere, but also in economics and broadly-understood business (Puffit, 1993). In this work, the method was used to assess revitalisation projects carried out under the *Local Revitalisation Programme of the City of Toruń for the Years 2007–2015*. Two factors are important in this procedure: the substantive preparation of the person conducting the procedure and the creation of ranking groups to evaluate individual projects (Montanari & Bracker, 1986; Puffitt & Prince, 2001).

The MMDM is a dynamic tool for exploring the needs and expectations of individual communities. The basic principle upon which the MMDM was developed is "creative explanation" (Johnson & Scholes, 2001). Here, the matrix was used to assess the revitalisation projects and the extent to which (through the implementation of these projects) the revitalisation needs of the residents have been met. The result is an evaluation of the post-revitalisation space as seen by its users. The only specified parameter of the matrix is the demand of the client group, i.e., the stakeholders of the revitalisation process rated on a scale of 1 to 5 (Kaźmierczak & Szulc, 2010). This parameter is marked on the x axis. The process of drawing up the MMDM was carried out in the form of an MMDM workshop during which the ranking groups evaluated individual projects according to the prepared evaluation criteria. The workshop took place in November 2020 and was attended by 60 people who came from different social groups and age ranges. It involved four ranking groups, each consisting of fifteen people. The first group comprised economically active people aged 27–45. The second ranked group consisted of fourth-year students of spatial management, the third of senior citizens, and the fourth of residents of Bydgoskie Przedmieście. All of these groups had links with Bydgoskie Przedmieście, either professional, residential, or private (leisure, shopping). Attention should be paid to the broad spectrum of people taking part in the workshop. It is important that the MMDM procedure involves different social groups who have different expectations and needs regarding the revitalisation process itself. This selection of ranking groups allowed the authors to objectivise the results of the research carried out (see Figure 1).

The first stage of the MMDM procedure is the preparation of an inventory of revitalisation projects based on the LRP. The next phase is to formulate the problems of the analysed area resulting from the

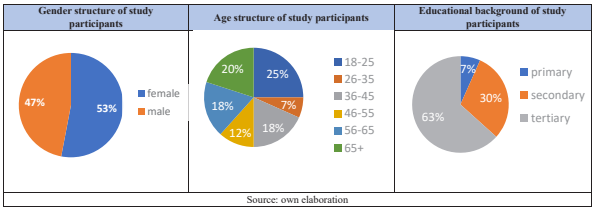


Fig 1. Basic information study participants
Source: own elaboration

LRP. Projects are analysed in the context of these problems, i.e., to what extent they have responded to the needs and problems diagnosed in Bydgoskie Przedmieście, and how they have revitalised the space. The next step in the procedure is to assess how important the diagnosed problems are in relation to the situation in the analysed area. The importance assessment is carried out by the ranking groups (workshop participants) based on a five-point Likert scale (very low; low; average; high; very high). The next stage of the work is to transform the problems into evaluation criteria that involve the calculation of an average rating for each problem and the assignment of weights. This produces weighted values of the problems, which will be used in the subsequent steps of the investigation.

Once the criteria have been constructed, each of the projects should be evaluated according to them. Project evaluation is based on indicating how a project, on a scale of 1 to 5, has mitigated the problems and thus met the local revitalisation needs that were identified at the initial stage of the procedure. The rating averages are then calculated and multiplied by the previously prepared weights. This yields weighted ratings of the projects, which are then added up. In this way we obtain the second value of the matrix, which is marked on the y axis.

The MMDM is plotted on x and y axes and is divided into four parts.

As a result, a typology of projects is created that groups projects according to how well they alleviate problems and meet revitalisation needs. The upper right-hand side includes projects that should be continued and monitored – these are premium-quality projects, i.e., those that have met local revitalisation needs to the greatest extent. Projects in the upper left-hand side of the matrix should be lobbied, supported and developed because they revitalise the space well – they are good-quality projects. In the lower right-hand section, we have projects to be reviewed and evaluated (these are projects that, with some modification, can meet revitalisation needs – "think and change"). The lower left-hand side of the matrix comprises projects that should be withdrawn (these are projects that did not meet revitalisation needs) – "run away" projects.

The MMDM shows how the completed revitalisation projects correspond to the needs indicated in the LRP and thus to the needs of the inhabitants, i.e., the stakeholders in the revitalisation process.

5. Research procedure and results

The MMDM method was applied in a workshop led by the authors of the paper. The procedure is presented in the Figure 3.

The first step in using the MMDM was to prepare the projects to be evaluated. They were selected from the projects annexed to the LRP. The next stage involved preparing and formulating the needs and problems of Bydgoskie Przedmieście, which resulted directly from the LRP analysis and were compatible with the programme assumptions. They included:

1. poor technical condition of buildings;
2. disorganisation of public spaces;
3. low level of economic activity;
4. social disintegration;
5. low sense of security.

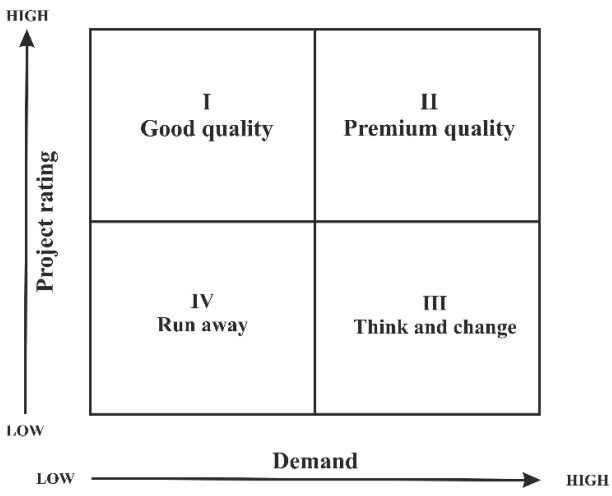


Fig. 2. Layout of projects on the MMDM
Source: own elaboration

These problems, later transformed into evaluation criteria, were the basis for rating revitalisation projects. The next stage was the prioritisation of the prepared problems by the ranking groups. The four ranking groups rated the importance of revitalisation problems on a scale of 1 to 5, where 1 meant a problem of the highest importance, and 5 of the lowest importance. The results of this procedure are shown in the Table 3.

Economically active people considered the low sense of security in Bydgoskie Przedmieście to be the most important revitalisation problem. For students, on the other hand, the poor technical condition of the buildings was the most substantial issue. The senior group did not grant a highest rating to any single problem. For seniors, the biggest problems were the poor technical condition of the buildings and the low sense of security. The same issues were identified by the residents of Bydgoskie Przedmieście.



Fig. 3. Procedure of the MMDM method
Source: own elaboration

The next step in the MMDM procedure was to transform problems into evaluation criteria. The weights were determined by assigning points to each level of importance according to the following assumption: 1 – 5 points, 2 – 4 points, 3 – 3 points, 4 – 2 points, 5 – 1 point. Thus, for example, the point average importance of the problem of social disintegration is 3.75. Subsequently, the sum of the average ratings was calculated. Criteria weights were calculated as the quotient of the average criterion rating and the sum of all average ratings. The calculated criteria weights are shown in the Table 4.

The next stage was to evaluate the projects according to the criteria and to determine the need for the implementation of each of the projects. The evaluation was based on a five-point Likert scale (very high, high, average, low, and very low). Each level was given a numerical counterpart of 5, 4, 3, 2, 1, respectively. The evaluation was carried out by the ranking groups and the results are presented in the tables below (see Tables 5 and 6).

The final demand for revitalisation projects to be taken into account in creating the MMDM is the point average of the demand ratings given by the ranking groups included in Table 5 in the "mean" column. This created one of the two dimensions of the matrix marked on the x axis. Table 6 shows the average rating of the projects according to the criteria. Workshop participants evaluated how each of the projects improved the criteria presented. An average was then drawn from the individual groups' partial ratings. The next stage of creating the MMDM was to compute the product of the average ratings of the criteria and the previously prepared weights (divided by 100) and to sum up the resulting values. This sum is the second dimension of the MMDM. This dimension is marked on the y axis. This gives two values for each project. The D-value, taking account of the demand for the project, and the E-value, which assesses how well the project addressed all the revitalisation needs identified at

Table 3. Importance of problems that revitalisation should solve, as indicated by workshop participants, i.e. ranking groups

No.	Revitalisation problems	Importance			
		G1	G2	G3	G4
1.	Poor technical condition of buildings	2	1	2	1
2.	Disorganisation of public spaces	2	2	3	2
3.	Low level of economic activity	3	3	4	3
4.	Social disintegration	2	2	3	3
5.	Low sense of security	1	2	2	1

Source: own elaboration
Legend: G1 – economically active people; G2 – students; G3 – seniors; G4 – residents

Table 4. Evaluation criteria for revitalisation projects and their weights

No.	Evaluation criterion	Weight
1.	Impact of the project on the improvement of buildings	23.68%
2.	Impact of the project on the improvement of organisation of public spaces	19.74%
3.	Impact of the project on the improvement of the level of economic activity	14.47%
4.	Impact of the project on social reintegration	18.42%
5.	Impact of the project on improving the sense of security	23.68%

Source: own elaboration

Table 5. Demand for individual revitalisation projects

No.	Revitalisation projects in Bydgoskie Przedmieście	Demand				
		G1	G2	G3	G4	Mean
1.	Revitalisation of the Spirit Foundation grounds	2	3	4	1	2.5
2.	Renovation of Municipal Kindergarten No. 4	1	2	1	2	1.5
3.	Development of Mickiewicza Street	1	3	1	1	1.5
4.	Revitalisation of Park Bydgoski	2	3	3	4	3.0
5.	Adaptation of the Childcare Association premises	3	3	5	1	3.0
6.	Modernisation of High School No. 1 gymnasium	3	3	4	5	3.8
7.	Extension of monitoring	1	2	3	2	2.0
8.	Revitalisation of the area at 32 Mickiewicza Street	2	1	3	4	2.5
9.	Revitalisation of elements of Zoobotanical Garden	1	2	2	1	1.5
10.	Revitalisation of Boulevard, from bridge to University Sports Association	3	1	2	3	2.3
11.	The Toruń John Paul II Run	2	3	4	5	3.5
12.	"Cultural revitalisation" project	2	1	2	1	1.5
13.	Michayland – Fantastic City for Kids	4	3	5	3	3.8
14.	Projects for the whole revitalised area including Bydgoskie Przedmieście	1	1	1	2	1.3

Source: own elaboration

the outset of the procedure. These data are included in Table 8.

The final step in the MMDM method is to create the matrix itself by marking the values obtained in Table 9 on the coordinate system. In this way, a complex evaluation of the individual revitalisation projects was made in the light of the opinions of the ranking groups. Each quadrant of the coordinate system is assigned a different project characteristic (Fig. 2).

There were four groups of projects:

- premium-quality projects, i.e., those with the best revitalisation potential;
- good-quality projects, i.e., those that should be lobbied, supported and developed because they revitalise well;
- "think and change" projects are projects that, with some modification, can meet revitalisation needs;
- "run away" projects are projects that have not met revitalisation needs.

The MMDM serves to determine whether a given project fulfils the assumptions of the LRP. The MMDM method placed the revitalisation projects within the LRP for Bydgoskie Przedmieście in all of the above-mentioned groups.

The projects implemented under the LRP were placed in each of the four distinguished groups of the MMDM. As a result, we have revitalisation projects that best revitalised Bydgoskie Przedmieście and met the needs of the inhabitants, and those that did little to eliminate these problems and further the revitalisation process itself. The best project in light of the MMDM was "Michayland – Fantastic City for Kids". Workshop participants believed that this project best met revitalisation needs (see Fig. 4).

Premium quality projects are those that have revitalised Bydgoskie Przedmieście to the greatest extent and responded to the needs of local communities. It is significant that the project to revitalise the Municipal Park and the Michayland Integration Festivities were rated highest. The latter is a cyclical event held in Park Bydgoski that integrates all residents of the district and beyond, i.e., it has an impact on the entire degraded area. The year 2019 marked the 25th edition of this project. Michayland is a project aimed at children but also at intergenerational integration and revitalising the public space of Park Bydgoski. It has a direct impact on two identified revitalisation problems: the disorganisation of public spaces and the disintegration of society. The matrix analysis shows that the project relating to the Municipal

Table 6. Average project partial ratings for criteria 1 to 5

No	Project	Weighted average ratings per criterion					
		C1	C2	C3	C4	C5	Total
1.	Revitalisation of the Spirit Foundation grounds	0.36	0.49	0.41	0.52	0.59	2.36
2.	Renovation of Municipal Kindergarten No. 4	0.83	0.36	0.33	0.42	0.71	2.65
3.	Development of Mickiewicza Street	0.59	0.39	0.51	0.42	0.43	2.34
4.	Revitalisation of Park Bydgoski	0.66	0.65	0.36	0.46	0.71	2.85
5.	Adaptation of the Childcare Association premises	0.59	0.49	0.36	0.55	0.47	2.47
6.	Modernisation of High School No. 1 gymnasium	0.54	0.59	0.36	0.52	0.47	2.49
7.	Extension of monitoring	0.83	0.30	0.26	0.37	1.02	2.77
8.	Revitalisation of the area at 32 Mickiewicza Street	0.90	0.49	0.48	0.39	0.78	3.04
9.	Revitalisation of elements of Zoobotanical Garden	0.71	0.79	0.36	0.42	0.36	2.64
10.	Revitalisation of Boulevard, from bridge to University Sports Association	0.83	0.26	0.33	0.37	0.59	2.38
11.	The Toruń John Paul II Run	0.43	0.69	0.22	0.37	0.47	2.18
12.	"Cultural revitalisation" project	0.47	0.39	0.41	0.37	0.59	2.23
13.	Michayland – Fantastic City for Kids	0.66	0.75	0.33	0.52	0.66	2.92
14.	Projects for the whole revitalised area including Bydgoskie Przedmieście	0.54	0.59	0.26	0.37	0.54	2.31

Source: own elaboration

Table 7. Weighted project ratings for criteria 1 to 5

No.	Revitalisation projects in Bydgoskie Przedmieście	Average grades according to criteria				
		K1	K2	K3	K4	K5
1.	Revitalisation of the Spirit Foundation grounds	1.5	2.5	2.8	2.8	2.5
2.	Renovation of Municipal Kindergarten No. 4	3.5	1.8	2.3	2.3	3.0
3.	Development of Mickiewicza Street	2.5	2.0	3.5	2.3	1.8
4.	Revitalisation of Park Bydgoski	2.8	3.3	2.5	2.5	3.0
5.	Adaptation of the Childcare Association premises	2.5	2.5	2.5	3.0	2.0
6.	Modernisation of High School No. 1 gymnasium	2.3	3.0	2.5	2.8	2.0
7.	Extension of monitoring	3.5	1.5	1.8	2.0	4.3
8.	Revitalisation of the area at 32 Mickiewicza Street	3.8	2.5	3.3	2.1	3.3
9.	Revitalisation of elements of Zoobotanical Garden	3.0	4.0	2.5	2.3	1.5
10.	Revitalisation of Boulevard, from bridge to University Sports Association	3.5	1.3	2.3	2.0	2.5
11.	The Toruń John Paul II Run	1.8	3.5	1.5	2.0	2.0
12.	"Cultural revitalisation" project	2.0	2.0	2.8	2.0	2.5
13.	Michayland – Fantastic City for Kids	2.8	3.8	2.3	2.8	2.8
14.	Projects for the whole revitalised area including Bydgoskie Przedmieście	2.3	3.0	1.8	2.0	2.3

Source: own elaboration

Table 8. Total project ratings

No.	Project	Total ratings	
		E	D
1.	Revitalisation of the Spirit Foundation grounds	2.4	2.5
2.	Renovation of Municipal Kindergarten No. 4	2.7	1.5
3.	Development of Mickiewicza Street	2.3	1.5
4.	Revitalisation of Park Bydgoski	2.9	3.0
5.	Adaptation of the Childcare Association premises	2.5	3.0
6.	Modernisation of High School No. 1 gymnasium	2.5	3.8
7.	Extension of monitoring	2.8	2.0
8.	Revitalisation of the area at 32 Mickiewicza Street	3.0	2.5
9.	Revitalisation of elements of the Zoobotanical Garden	2.6	1.5
10.	Revitalisation of Boulevard, from bridge to University Sports Association	2.4	2.3
11.	The Toruń John Paul II Run	2.2	3.5
12.	"Cultural revitalisation" project	2.2	1.5
13.	Michayland – Fantastic City for Kids	3.0	3.8
14.	Projects for the whole revitalised area including Bydgoskie Przedmieście	2.3	1.3

Source: own elaboration
(E – project evaluation; D – demand for a given project)

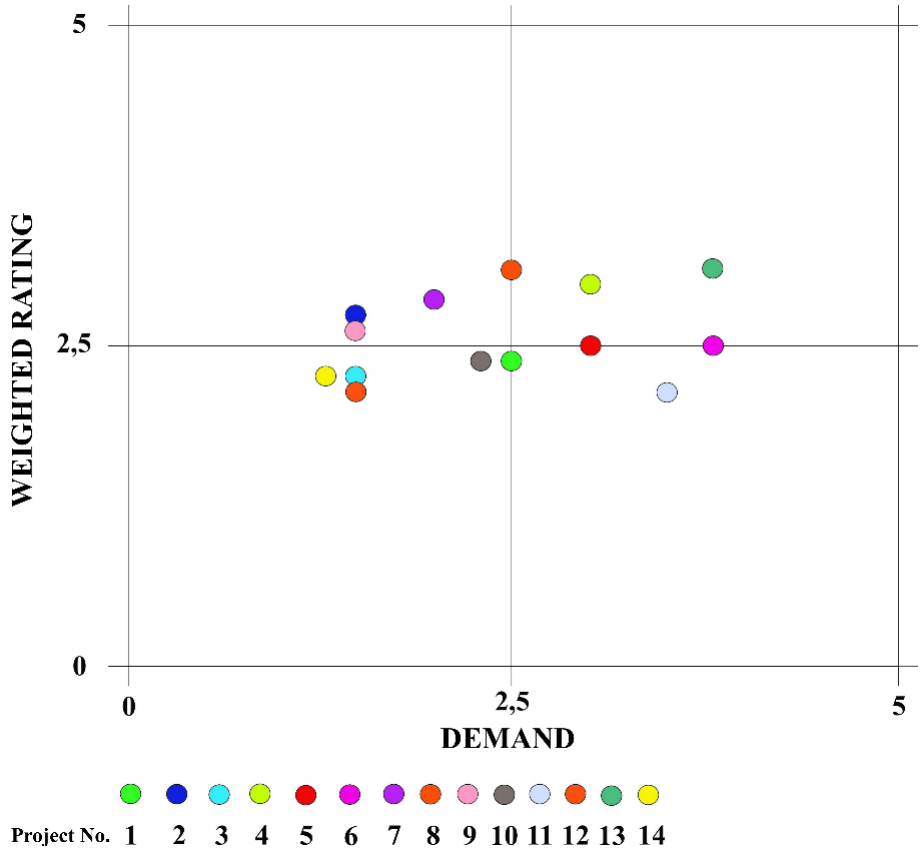


Fig. 4. MMDM containing revitalisation projects implemented under Toruń LRP 2007–2015 in Bydgoskie Przedmieście
Source: own elaboration
Explanation:1. Revitalisation of the Spirit Foundation grounds; 2. Renovation of Municipal Kindergarten No. 4; 3. Development of Mickiewicza Street; 4. Revitalisation of Park Bydgoski; 5. Adaptation of Childcare Association premises; 6. Modernisation of High School No. 1 gymnasium; 7. Extension of monitoring; 8. Revitalisation of the area at 32 Mickiewicza Street; 9. Revitalisation of elements of Zoobotanical Garden; 10. Revitalisation of Boulevard, from bridge to University Sports Association; 11. The Toruń John Paul II Run; 12. "Cultural revitalisation" project; 13. Michayland – Fantastic City for Kids; 14. Projects for the whole revitalised area including Bydgoskie Przedmieście

Park is characterised by high demand (and, thus, further revitalisation works are taking place there) and a relatively high weighted rating. The park in Bydgoskie Przedmieście is a place for residents to meet, relax and unwind. It is a space recognisable in Toruń and characteristic of the city. A wide range of tasks have been undertaken in the park, including reorganising the alleys, modernising the paving, new greenery planting, and restoring the fountain.

The results attest to the high need for socio-integrative projects embedded in a green environment. Good-quality projects are good revitalisation projects that have a positive impact on society and space. They improve the quality of space dedicated to the very young and to the general safety of Bydgoskie Przedmieście.

"Think and change" projects are projects for which there was relatively high demand, but whose final evaluation was not satisfactory. In order to further implement this type of projects, it would be necessary to modify the project assumptions to correspond to revitalisation needs. A sporting event was placed in the third group. Its form may not be acceptable and attractive to the entire local community, but perhaps only to the more physically active. However, there is certainly an integration potential that should be exploited.

The final, fourth group of projects is that of "run away" projects. These are the projects that least met the needs of the inhabitants, for which there was the lowest demand, and that thus did not contribute to the revitalisation of the area. This group included various infrastructural projects,

Table 9. Tabular presentation of the MMDM matrix

Premium quality	Good quality	Think and change	Run away
1. Revitalisation of Park Bydgoski 2. Michayland – Fantastic City for Kids	1. Renovation of Municipal Kindergarten No. 4 2. Revitalisation of elements of Zoobotanical Garden 3. Extension of monitoring	1. The Toruń John Paul II Run	1. Projects for the whole revitalised area including Bydgoskie Przedmieście 2. Development of Mickiewicza Street 3. "Cultural revitalisation" project 4. Revitalisation of Boulevard, from bridge to University Sports Association

Source: own elaboration

such as the revitalisation of Mickiewicza Street (treated by residents as a simple renovation), the renovation of the Vistula boulevards and the "Cultural Revitalisation", i.e., an open-air poster gallery, which people found incomprehensible.

To sum up, the projects that received the highest ratings and at the same time did the most to revitalise the space in Bydgoskie Przedmieście were those of an integration and environmental character and those improving security. Lowest-rated were infrastructural projects or those dedicated to narrow social groups. The remaining revitalisation projects, not included in the four groups, cannot be assigned to a specific group due to their location on the matrix. They are on the demarcation lines of the project categories, but it is significant that most of them remain in balance, i.e., there is a convergence between the existing demand for such projects and their mitigation of revitalisation problems.

6. Discussion

The MMDM allows for detailed characterisation of individual revitalisation projects, evaluation and determination of the extent to which they have revitalised a given architectural and social space. An appropriate reformulation of the MMDM allows conclusions to be drawn as to whether the revitalisation projects have met the needs identified in the strategic documents (Szulc, 2013).

The MMDM method helps evaluate each of the projects implemented within the framework of local revitalisation programmes and thus verify which initiatives revitalise a given area and which do not. It is characterised by increased contact with respondents and is less formal. It involves the local community and therefore has an important humanist and pro-social dimension. It is carried out in the form of a workshop, which is an obligatory stage in the MMDM method. The workshop takes the form of meetings for ranking groups, allowing participants to exchange experiences, views and insights related to the revitalisation process. Social participation is an important element of the revitalisation process and should take place at each of its stages. It provides an opportunity for the community to co-determine the transformation of the urban fabric.

The MMDM procedure presented in this article allows for a broad evaluation of the entire revitalisation process by evaluating each individual project, because it concretises in the revitalisation space the evaluation of individual projects, i.e., the degree to which revitalisation needs are satisfied in each instance. It should be considered innovative because it can be implemented at all stages of the revitalisation process. It can serve as a tool for selecting revitalisation projects, i.e., as *ex-ante* evaluation (Szulc, 2013). In this way, the projects will be adjusted to the expectations of the inhabitants – stakeholders in the process. The MMDM can also be used when evaluating projects during revitalisation activities. The use of the method for ex-post evaluation of the revitalisation process

in this article is a highly innovative approach to the issue. It allowed the authors to diagnose the implementation of revitalisation projects in the context of demand for them and the inhabitants' assessment. The results obtained in this way make it possible to correct revitalisation measures in order to focus on the types of projects that are most needed by the users of the revitalisation space in subsequent perspectives. Due to the complexity of the revitalisation process, its monitoring and evaluation is an extremely difficult yet necessary endeavour. The evaluation of revitalisation results should bring together all levels of the process, with particular emphasis on the social and spatial facets.

Revitalisation processes are evaluated on the basis of different research methods. Two streams can be distinguished: qualitative and quantitative. The qualitative stream includes the multi-criterion QAT (Quality Assurance Testing) method of analysis and evaluation of revitalisation projects. It was developed during the Hous-Es project within the European URBACT programme, using the findings enshrined in the Rotterdam *Urban Acqui* (2004), the *Bristol Accord* (2005), and the *Leipzig Charter* (2007). The QAT method includes a technical assessment of the project based on an evaluation questionnaire. The questionnaire is structured so that the answers given are binary in order to simplify the subsequent interpretation of the results (Bury, 2010). Applying this method to the analysis and evaluation of revitalisation makes it possible to focus on the technical dimension of the process, while further extensions of the method help show the entirety of revitalisation transformations.

Most often, revitalisation changes are evaluated using an indicator (quantitative) method, which is relatively cheap but inaccurate (Ciesiółka, 2019). Its first phase consists in preparing demographic, technical and economic indicators based on publicly available statistical data or coming from the commune's own resources. These indicators relate to the situation before the revitalisation process – baseline data – and after the revitalisation has taken place. This method allows us to learn whether the technical parameters of the revitalisation process have improved, e.g., whether the number of buildings in poor technical condition has decreased. It also shows social changes, e.g., whether the proportion of people on social assistance has dropped (Peng, Lai & Zhang, 2015). This method provides hard data about the revitalisation carried out but does not refer to individual revitalisation projects – it only evaluates the process as a whole. It is not possible to correct ongoing activities based on the results of this method. It also does not provide information on how local communities evaluate revitalisation (McCulloch, 2000).

Another method for evaluating revitalisation activities is participatory observation and the individual in-depth interview method used by Hermawan to evaluate the implementation of a revitalisation programme at the Van Den Bosch Fort site in Ngawi, Indonesia (Hermawan, Sholihah & Pramanasari, 2019). The revitalisation transformations were assessed by the researchers based on their observations, which included an analysis of the spatial transformations, i.e., the use of former military sites, the adaptation of buildings and the materials used for this purpose. Interviews with residents and users of the space included a social analysis of the activities carried out, mainly focusing on the tourist use of the fort.

The MMDM method allows for a combination of the methods mentioned above. Its structure guarantees free selection of project evaluation criteria (which may come from different levels of the process) and a focus on both technical elements and social problems; thus, the method enables a multifaceted approach to the evaluation of the revitalisation process. The prepared evaluation criteria can serve as indicators that, if properly interpreted and prepared, will help rate the impact of a given project on the revitalised space. The MMDM is established based on workshops with residents, which are an essential part of conducting the matrix procedure. The workshops serve not only to prepare input data for the matrix, such as the demand for and evaluation of projects, but also to hold interviews and discussions with inhabitants (local communities) about the revitalisation process carried out.

7. Conclusions

According to the research, projects of an integration and environmental character and those improving security were the most appreciated and at the same

time had the best revitalising effect on the space of Bydgoskie Przedmieście district. The lowest ratings were given to infrastructural projects or those dedicated to narrow social groups (alternative arts). The MMDM method should be considered an appropriate tool for evaluating revitalisation. One can also draw further conclusions that revitalisation in Poland should have a "green" character. This "green revitalisation turn", understood as a growing social demand for revitalisation of green areas, is particularly relevant in the context of negative climate change – greenery offsets it and improves the overall psycho-motor condition of people in general. The research has also shown that revitalisation should be socially inclusive, i.e., oriented towards the needs of local communities and their participation in the revitalisation process.

The authors are aware that the MMDM method is not a perfect tool and should be continuously modified and improved. Risks in conducting the matrix procedure include workshop participants' level of knowledge about revitalisation. This is an extremely important element that can affect the results of the analysis.

In summary, the MMDM can be combined with other methods, such as surveys. They can work in synergy to yield a comprehensive evaluation of the revitalisation process. The MMDM method is an extremely flexible tool that should be widely used in research. Therefore, it is justified to recommend its implementation in assessments, evaluations and summaries of processes, undertakings, and projects concerning revitalisation but also other urban processes and activities.

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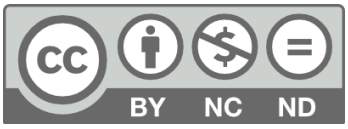
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BIBLIOMETRIC ANALYSIS OF RESEARCH ON URBAN RESILIENCE: TOWARDS A SYSTEMATIC FRAMEWORK

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A b s t r a c t

Amid increasing challenges associated with urbanisation and climate change, urban resilience has become a central focus in scientific research. The rapid evolution of this field has resulted in fragmented theoretical perspectives, which hinder a comprehensive interpretation of current studies. This study aims to identify the principal dimensions of urban resilience and to systematise them through bibliometric analysis. The identified research gap is the absence of a coherent conceptual framework that integrates contemporary trends in urban resilience research. The study introduces an original conceptual framework comprising five dimensions of urban resilience and an overarching dimension of disruption that integrates the remaining components. The methodology includes a literature review and bibliometric analysis of works published between 2010 and 2025 and indexed in the Scopus database, utilising keyword co-occurrence analysis in VOSviewer. The findings reveal that recent research predominantly addresses administrative-managerial and infrastructural-spatial dimensions, whereas environmental, economic, and social dimensions are comparatively underrepresented. This study consolidates the existing body of research on urban resilience. It presents a conceptual framework for green urban resilience, which may serve as a basis for future investigations into the development of the urban resilience concept.

Keywords: green urban resilience, environment, dimensions, city, urban planning, climate change

1. INTRODUCTION

Contemporary cities face growing social, economic, and governance challenges in a multi-crisis environment marked by intense urbanisation, demographic pressures, social inequalities, and the ongoing climate crisis. These phenomena deepen tensions in urban systems, weakening their ability to ensure a high quality of life for residents and maintain stable development. The accumulation of social and economic problems often coexists with environmental challenges, increasing cities' vulnerability to various crises.

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In the context of ongoing civilizational development, cities should be viewed as complex, dynamic, and nonlinear systems in which interconnections among the social, economic, spatial, and environmental spheres determine their functioning [8], [91]. In the chaos theory approach, even small disruptions can lead to disproportionately large changes in the city's structure and organisation [67], making development difficult to predict. Consequently, cities experience both short-term disruptions and long-term transformations. Floods illustrate such disruptions, affecting an entire spatial unit while generating economic, infrastructural, spatial, and social problems [90]. Their effects are not limited to the material dimension; they also affect residents' psychological well-being. In response, residents develop adaptive mechanisms such as selective attention or social withdrawal, which can limit their capacity to respond to everyday disruptions [113].

From the ecosystem approach, a city functions as a system of interconnected elements encompassing society, infrastructure, and the natural environment [109]. Disturbances in one component can therefore unbalance the whole system. For example, increasing urbanisation at the expense of green spaces or air pollution negatively impacts living conditions, intensifying urban heat islands [25]. In this context, green areas constitute a crucial component of the city's structure, determining quality of life and environmental stability [95].

The concept of urban resilience [106], [14], [71] responds to the growing complexity and vulnerability of cities to various crises. UN-Habitat [46] defines it as the ability of an urban system to maintain operational continuity in the face of shocks and stresses. A key element of resilience is not only the ability to withstand disruptions but also to adapt and transform towards more sustainable development [41]. The literature emphasises that resilience remains closely linked to sustainable development, highlighting urban systems' ability to learn and adapt [2], [77]. While sustainable development focuses on balancing environmental, social, and economic dimensions, urban resilience emphasises the capacity to absorb disruptions and maintain key functions during crises [92].

From this perspective, cities' ability to respond to shocks (sudden events such as floods, fires, or hurricanes) and stresses (long-term processes such as climate change or demographic pressure) is particularly important, as is the time available for the urban system to undertake effective adaptation measures. The speed and effectiveness of the urban organism's response to disruptions largely determine its resilience and capacity for further development [118].

2. URBAN RESILIENCE: THEORETICAL PERSPECTIVE

The concept of urban resilience dates back to the 19th century. According to Masik [69], the first definition of resilience appeared in the Encyclopaedia Britannica and referred to the physical property of a body that is deformed by compressive forces to regain its size, i.e., return to its original state [85]. Currently, many different definitions of urban resilience can be found in the literature [78], [81]. The concept of urban resilience has evolved alongside research on the impact of negative stimuli on the condition and behaviour of urban centres. In his groundbreaking work, Holling [50] first introduced the concept of ecological resilience, defining it as the ability of a system to absorb disturbances and reorganise without losing its ability to function. Building on this, the adaptive cycle proposed by Holling et al. [51] describes the dynamics of change in complex systems, including cities, through four successive phases: exploration, consolidation, destruction, and renewal. The exploration phase represents a period of dynamic growth and the search for new development paths with high system flexibility. The consolidation phase is a period of structural stabilisation, accompanied by a decline in adaptive capacity. The destruction phase involves the sudden collapse of the existing order and the loss of some resources as a result of the crisis. The renewal phase involves the reorganisation of the system and the creation of new development structures. In this approach, the process of transitioning between

phases is sometimes interpreted as analogous to the phenomena of degradation and reactivation of urban areas (e.g., in the context of revitalisation), although it does not mean a simple return to a previous state, but rather its transformation [68].

The Resilience Alliance, an international, multidisciplinary research organisation founded in 1999 that studies the dynamics of social-ecological systems, adopts an understanding of urban resilience similar to Holling's. According to the Resilience Alliance [94], urban resilience refers to the capacity to cope with emerging adverse phenomena by adapting to existing conditions. This definition is supplemented by Ahern [2], who emphasises that resilience is a process of continuous learning and adaptation to changing conditions. In the context of resilience, the Intergovernmental Panel on Climate Change [53] further highlights an important aspect of adaptation to climate change: cities should reduce their vulnerability to adverse impacts and increase their capacity to recover quickly.

A different approach to urban resilience is presented by Leichenko [63] and Chelleri [18], who emphasise the importance of appropriate governance for urban resilience. Leichenko [60] points out that urban resilience focuses on the ability of cities to manage risks amid uncertainty and adapt to threats originating from the natural environment as well as those generated by human activity. By contrast, Chelleri [18] does not focus his definition specifically on risk management but indicates that urban resilience is a comprehensive approach to urban management that should take into account the ability to withstand challenges across various temporal and spatial scenarios.

One way to understand a city is through a holistic approach, considering it as a complex system in which all its elements and processes are interconnected [121]. In this approach, the city is analysed not only as the sum of its parts but as a whole in which interactions between individual components are crucial to understanding its functioning and dynamics [65]. David Godschalk [42] conducts research on resilience, drawing a similar understanding of the city to Li and Zhao's, and points out that it is a multidimensional process. Resilience should consider the integration of all urban systems: infrastructure, economy, environment, and society, i.e., a holistic approach to urban systems, without rejecting any of them [42]. Another important approach to building urban resilience is based on innovation, which often catalyses change in the city [64]. Davoudi and his team [23] base their understanding of urban resilience on this innovative approach to the city. They point out that resilience is the ability to adapt to future challenges. This ability can be achieved through innovations in the management of urban spaces and through the development of adaptation policies, including those stemming from Nature-Based Solutions. Meerow [75] approaches the issue of urban resilience similarly to Davoudi, also focusing on innovations in creating resilience, such as green roofs, Miyawaki's forest pockets, or smart city technologies, but in her considerations, she indicates that the time it takes for the disturbed urban organism to return to a state of equilibrium is important. Meerow and Newell [74] proposed new concepts: an approach to defining urban resilience. Their definition emphasises that resilience is not only the ability to return to a state of equilibrium but also to evolve in response to change and uncertainty.

An important aspect of urban resilience is urban greenery, which strengthens the functioning of the city as a complex socio-ecological system. The environmental approach to urban resilience is based on increasing cities' ability to maintain equilibrium and adapt by protecting and restoring ecosystems [114], [44], leading to the implementation of solutions such as green infrastructure and preparations for future environmental challenges [76]. Consequently, green areas become one of the key elements supporting this resilience. Their importance is growing, especially amid climate change, which is increasing the frequency of extreme weather events such as heat waves, floods, and droughts. In response to these threats, urban greenery serves as a nature-based solution that mitigates their effects [79]. Increasing biologically active surfaces promotes stormwater retention, reducing the risk of flooding and slowing stormwater runoff [36], thus strengthening the resilience of urban infrastructure

[60]. At the same time, the impact of green spaces extends beyond the environmental dimension and affects the social sphere, as their availability improves residents' mental well-being, supports regeneration, and reduces stress [116]. This, in turn, promotes greater use of public spaces, such as parks and community gardens that integrate residents and thus strengthen social capital [54], an element of urban resilience. In addition, green spaces are a crucial element of urban policies and strategic documents, as urban greenery also brings economic benefits. It increases property values, enhances the city's investment attractiveness, and reduces costs related to public health and extreme weather events. For this reason, contemporary urban development strategies consider green infrastructure a tool for strengthening cities' potential [49].

The concept of urban resilience, based on research conducted in numerous centres, emphasises the integration of management, technology, innovation, and environmental protection to increase cities' ability to adapt, survive, and thrive in the face of crises [17].

3. AIM, METHODS AND TIMEFRAME OF THE STUDY

The aim of this study is to conduct a review and bibliometric analysis of the scientific literature on urban resilience to identify current and dominant dimensions of the concept.

The study was divided into three stages:

- The first, conceptual stage included establishing the study objective, defining the time frame, and conducting a literature review.
- The second, analytical stage involved quantitative, keyword-based bibliographic and network analyses using VOSviewer.
- The third, synthetic stage included a synthesis of the results and conclusions, along with a summary of the study.

The analyses included:

1. Selection of the primary database based on the occurrence of the main search phrase "urban resilience" in the title, abstract, and keywords in Scopus and Web of Science according to the query (TITLE ("urban resilience") OR ABS ("urban resilience") OR KEY ("urban resilience")) AND PUBYEAR > 2009 AND PUBYEAR < 2026.
2. Extraction of articles from the primary database containing the term in their keywords according to the query KEY ("urban resilience") AND PUBYEAR > 2009 AND PUBYEAR < 2026.
3. Creation of a keyword co-occurrence network map.
4. Definition of clusters representing dimensions of urban resilience, constituting complementary search phrases.
5. Quantitative analysis of the total number of occurrences of the main and complementary search phrases in the title, abstract, and keywords in Scopus.
6. Creation of a keyword co-occurrence network map for the environmental dimension of urban resilience based on a database of articles prepared based on the query (TITLE-ABS-KEY ("urban resilience") AND TITLE-ABS-KEY ("environment") AND TITLE-ABS-KEY ("green")) AND PUBYEAR > 2009 AND PUBYEAR < 2026

Bibliometric analysis quantitatively examines scientific publications and their relationships to identify research trends, dominant topics, knowledge structures, and development dynamics within a discipline.

It uses bibliographic data, including citations, authorship, keywords, and scientific collaborations [24]. It also relies on network analysis and keyword co-occurrence to examine keyword frequencies [19]. The study used VOSviewer to identify keyword relationships, group them into thematic clusters, structure the research area, and determine dominant dimensions [112].

The timeframe of the study covers the years 2010–2025. In 2010, the term "urban resilience" began to function as a clearly defined and intensively developed area of research [75]. Over the past decade or so, the number of scientific papers has increased significantly, reflecting the growing importance of urban resilience issues. This timeframe captures the most current research directions. The analysis utilized keywords exported directly from Scopus, without additional normalization or unification before import into VOSviewer. This methodological choice was made to accurately represent the structure of contemporary scientific discourse on urban resilience. Preserving the original keywords ensures consistency with Scopus metadata and minimizes the risk of subjective decisions regarding the merging of terms with potentially distinct meanings.

3.1. Novelty of the research

Despite the dynamic development of research on urban resilience, previous studies have focused primarily on defining the concept of urban resilience or analysing its selected dimensions. Proposed classifications in the literature vary in both the number and scope of the identified dimensions. However, there is a lack of an analytical framework based on quantitative analysis of current scientific literature that would organise urban resilience research.

The presented research addresses this gap by developing an analytical framework for urban resilience based on bibliometric analysis and keyword co-occurrence analysis. This allowed for the identification of five dimensions of urban resilience and an overarching meta-dimension, which is not just another dimension of resilience but rather serves as an integrating factor for all the other dimensions. Thus, the proposed framework expands on existing models of urban resilience, organising their structure and establishing a hierarchy of relationships between specific areas of research.

The analyses also enabled further development of the environmental dimension of urban resilience through the conceptualisation of green urban resilience. The contribution of this article is not to formulate a new theory of urban resilience but to integrate dispersed research streams. In the proposed approach, green urban resilience expands upon the environmental dimension of urban resilience, highlighting the crucial role of natural resources and green infrastructure in shaping a city's ability to adapt, absorb, and transform in response to contemporary threats.

4. RESEARCH RESULTS

Initially, records from the Web of Science (4,662) and Scopus (6,812) databases containing the keyword phrase "urban resilience" in the title, abstract, or keywords were identified. The results were then compared to detect and remove potential duplicate records across the databases. Scopus was chosen as the reference database for subsequent analysis due to its greater number of indexed publications and broader metadata coverage. Accordingly, all bibliometric analyses were performed exclusively on records from Scopus. In the final stage of data preparation, 2,268 Scopus publications that included the phrase "urban resilience" specifically in their keywords were selected. This refined dataset served as the foundation for further bibliometric analyses based on keyword co-occurrence.

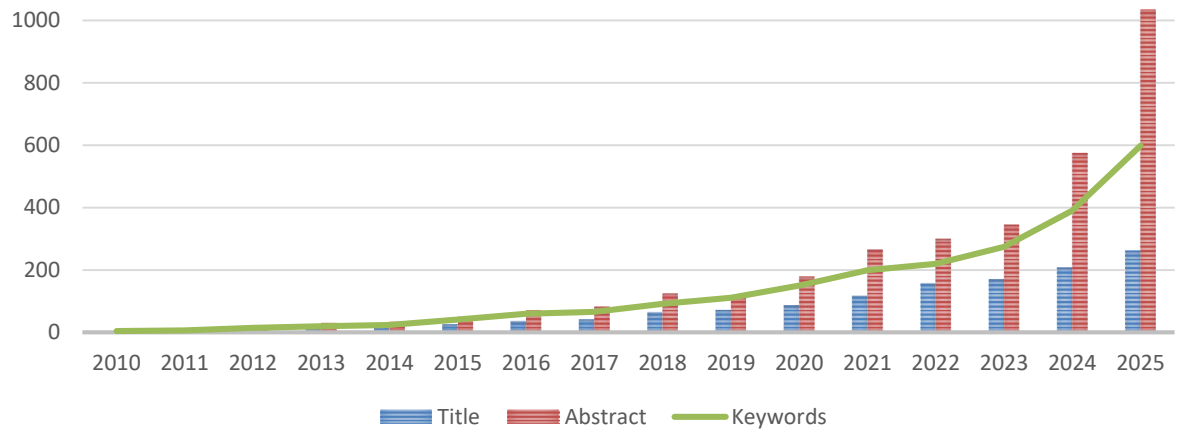


Fig. 1. Time distribution of the main search phrase in the title, keywords and abstract in 2010–2025
Source: own study based on the Scopus database

Analysing the annual frequency of occurrence of the main search phrase shows that interest in urban resilience has increased since 2018, with a particularly marked rise in occurrences in the abstract and keywords. Since 2018, there has been a steady increase in the number of publications addressing this topic in their research. The observed increase in publications during the analysed period may be associated with significant global events, such as the COVID-19 pandemic, which has intensified scholarly interest in urban resilience. Nevertheless, given the quantitative nature of the analysis, it is not possible to attribute these changes exclusively to this factor. Figure 1 illustrates the annual distribution of the main search phrase in publications indexed by the Scopus database.

After selecting the database, a network analysis was conducted using keyword co-occurrence analysis. At this stage of the research, a curated dataset comprising 2,268 scientific publications sourced from the Scopus database was utilised. This procedure enabled the development of a map of relationships between keywords and the identification of clusters reflecting the main research dimensions. As Gołaszewska-Kaczan [43] points out, map readability is important when creating keyword co-occurrence maps. Therefore, this study included keywords that occurred at least five times in the extracted dataset. Figure 2 presents the resulting keyword co-occurrence map.

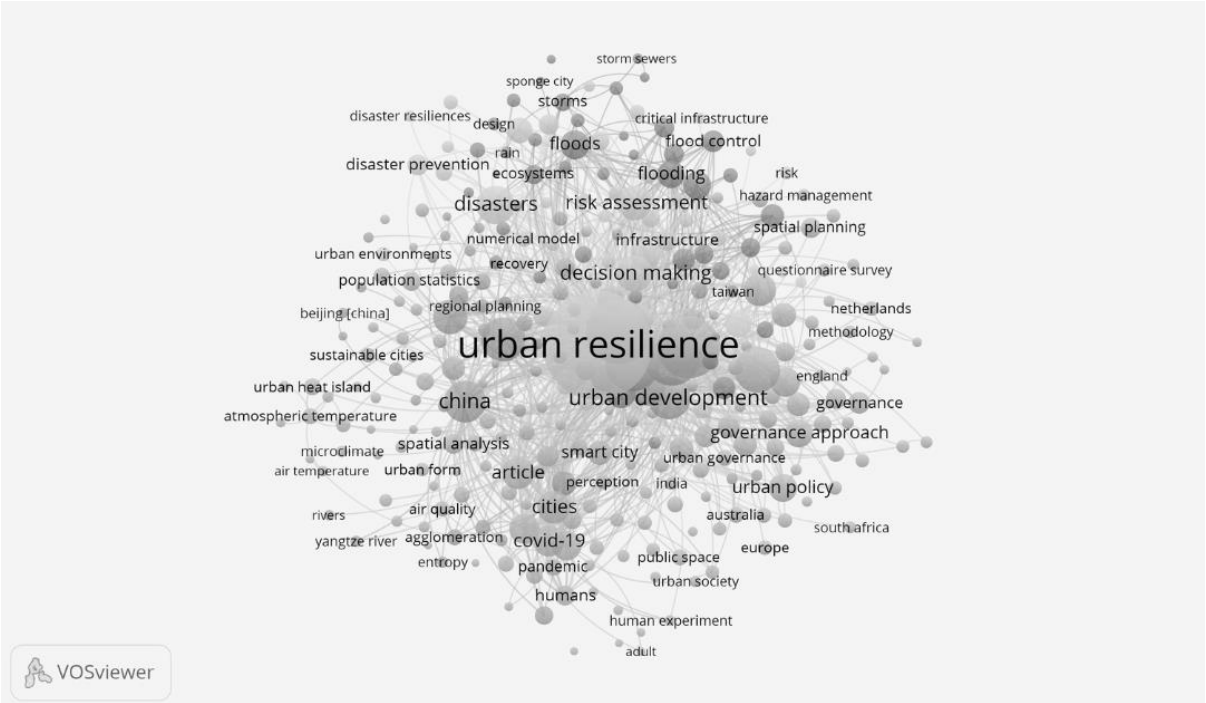


Fig. 2. Network co-occurrence of keywords
Source: prepared based on Scopus and VOSviewer.

Using the keyword co-occurrence procedure allowed us to identify the dimensions in which the topic of urban resilience is addressed, enabling further analysis of the concept's individual dimensions. Network analysis identified five main clusters (environment, society, infrastructure, economy, and governance) and one overarching cluster that serves as an integrating node connecting the remaining research areas. These thematic categories formed the basis for defining the current dimensions of urban resilience. Five current dimensions were identified: administrative-managerial, infrastructural-spatial, environmental, economic, and social.

After identifying the dimensions currently represented in scientific discourse on urban resilience, we examined their quantitative representation in the scientific literature. The identified main clusters were adopted as supplementary search phrases for further bibliometric analyses.

In this part of the study, the main search phrase was combined with a supplementary search phrase. The resulting pairs of search phrases were analysed for co-occurrence in the title, abstract, and keywords in the Scopus database. Based on the two-component analysis, the social and economic dimensions remain relatively underdeveloped in urban resilience research. Environmental issues, despite their growing importance amid the ongoing climate crisis, do not occupy a leading position within the structure of connections to the concept of urban resilience. Thematic areas focused on governance and infrastructure dominate (see Table 1).

Table 1. Analysis of the occurrence of the main search phrase and the supplementary search phrase in the Scopus database

Main and supplementary search phrases	Title	Abstract	Keywords	Total
urban resilience + society	8	186	30	224
urban resilience + environment	19	699	137	855
urban resilience + infrastructure	50	929	317	1,296
urban resilience + economy	19	213	93	325
urban resilience + management	57	878	537	1,472

Source: own study, prepared based on the Scopus database (as of February 7, 2026)

The final part of the bibliometric analysis included in-depth studies of the environmental dimension of urban resilience. A search of scientific articles containing the search phrases urban resilience, environment, and green in their titles, abstracts, and keywords was conducted in the Scopus database. Based on the database search, 142 scientific articles published between 2010 and 2025 were selected. To identify the dominant research directions related to the environmental dimension of urban resilience, a keyword co-occurrence analysis was conducted. The network structure revealed four distinct but interrelated clusters, reflecting separate subdimensions of research on environmental aspects of urban resilience.

5. DIMENSIONS OF URBAN RESILIENCE: PROPOSED ANALYTICAL FRAMEWORK

The analyses revealed an integrating node: the disruption dimension. Its identification indicates that various disruptions are integral to urban resilience. It is characterised by the highest level of interconnection and strong correlation with other dimensions, indicating its overarching nature.

This high centrality means the disruption dimension serves as an integrating axis around which the remaining elements of the urban resilience system are organised. It does not describe a single, discrete area of a city's functioning, but rather refers to a universal set of stimuli and pressures affecting all its spheres. Consequently, it cannot be treated on an equal footing with other sectoral dimensions that relate to specific areas.

The disruption dimension should therefore be interpreted as a set of primary determinants influencing the individual dimensions of resilience: administrative and managerial, infrastructural and spatial, environmental, economic, and social. Disruptions serve as initiating factors and determine the development and specificity of each dimension. Their nature, scale, and frequency define management needs, shape infrastructure development and spatial planning, determine environmental pressures, influence the stability of economic systems, and impact social processes.

From this perspective, the disruption dimension is paramount, as it establishes an interpretative framework for the other dimensions and determines how they are identified and operationalised. However, it does not constitute a standalone category within urban resilience but rather a meta-dimension that permeates the others and gives them analytical meaning, thereby confirming its central

role in structuring the entire concept. This distinction should be kept clear when interpreting the framework.

5.1. Administrative-managerial dimension

Urban resilience in the context of urban governance refers to the ability of city authorities and management systems to anticipate, prepare for, respond to, and adapt to challenges such as natural disasters, climate change, and social and technological crises [41]. In the literature on urban resilience, it is often analysed within the framework of multi-level governance, encompassing the national, regional, and local levels [28]. A key element in managing urban resilience at the national level is the creation of a supportive framework of policies and principles that should positively impact resilience [20]. Systems thinking is crucial in developing national policies. A systems approach to framing urban policies is crucial for understanding and managing the complex interdependencies between various elements of urban resilience. Without an appropriate legal framework, legislative tools, and programmes, building urban resilience would be significantly hindered [104]. Elkhidir et al. [32] point to the need to establish national resilience knowledge networks that would institutionalise knowledge sharing, collaboration, and the standardisation of resilience approaches, thereby creating consistent national standards for urban resilience.

According to Dieperink [28], the regional level in urban resilience management serves as a coordination point between national policy and local activities, particularly in spatial planning, social policy, water management, and flood risk management. It enables the integration of multiple municipalities and institutions within a single functional area, thereby increasing the effectiveness of resilience-building.

From a local perspective, as Struggles [107] points out, local government is closest to the problems that may arise in cities. Struggles also points out that a crucial element in resilience management at the local level is cooperation with other levels of government, as well as public and private entities. Furthermore, the local dimension of resilience activities must be consistent with national policy principles, but above all, take into account the principles of sustainable development [16].

As Knodt et al. [57] point out, the systemic management model becomes particularly important in crisis situations, when rapid and efficient information exchange becomes crucial. The authors distinguish three basic types of critical infrastructure management at the local level: a hierarchical model, based on formal structures and centralised decision-making; a network model, based on cooperation and partnerships; and a market model, utilising competitive mechanisms. In this context, network management is particularly important, as it constitutes a crucial tool for shaping the administrative and managerial dimension of urban resilience. It enables effective coordination of activities among the various entities involved in the city's functioning, which is especially important in crisis situations [88].

The dimension of resilience management at the local level is characterised primarily by the flexibility of local government bodies and their proximity to emerging crises [31]. Local authorities and organisations are closer to the real challenges and needs of residents, which enables a faster response to crises [99]. Local governance also encompasses collaboration with residents, non-governmental organisations, and local businesses in decision-making processes, including the development of district-level adaptation plans, e.g., integrating green urban spaces into blue-green infrastructure [35]. Effective urban governance in the context of urban resilience requires synergy between central and local activities. Local entities ensure flexibility and adaptation to local conditions, while central institutions provide the framework, financing, and broad-based coordination. Only such a multi-level approach will enable the building of cities resilient to future challenges.

5.2. Infrastructural-spatial dimension

Infrastructure plays a key role in building urban resilience [92]. High-quality technical infrastructure increases cities' ability to cope with threats by minimising losses and enabling the rapid restoration of normal urban functions [62]. It encompasses transportation, energy, water and sewage networks, flood protection systems, and crucial blue-green infrastructure (e.g., parks and retention reservoirs) in the context of a climate crisis. Infrastructure and urban space play a key role in building urban resilience, encompassing not only technical aspects but also the design and organisation of green areas and public spaces, as well as the city's functional and spatial structure. As emphasised by researchers [122], [93], [5], [61], appropriate spatial management, the integration of blue-green infrastructure, and resident participation in planning can mitigate the impact of threats and strengthen cities' adaptive capacity.

Urban infrastructure must be properly planned to minimise the negative impact of potential disruptions. It can be designed based on the principles of diversification and decentralisation of systems, so that the failure of one element does not paralyse the entire system, as discussed extensively by Rinaldi, Peerenboom, and Kelly [98] in their analysis of critical infrastructure interdependencies and by Ouyang [84] in their review of the literature on infrastructure system resilience. Planning based on risk analysis and the identification of intersectoral dependencies is also crucial, allowing for the mitigation of cascading failures and ensuring business continuity in crisis situations [86], [39]. Furthermore, intelligent management of urban infrastructure is crucial [13]. In the context of urban resilience, this means using advanced technologies, data, and innovative strategies for design, monitoring, and management that increase resilience to disasters, climate change, and other challenges [103]. Intelligent infrastructure management, such as early warning systems, increases the ability to respond quickly to crises [22].

Damage to key infrastructure elements can lead to cascading failures in urban systems, such as blackouts, transport disruptions, or water shortages, thereby weakening a city's resilience [108]. Sustainable and resilient infrastructure (e.g., earthquake-resistant buildings, stormwater management systems) reduces the risks associated with extreme events such as floods and droughts [119].

5.3. Environmental dimension

The environmental dimension of the urban resilience concept focuses on cities' ability to adapt through their environmental components. The natural environment plays a key role as an adaptive factor. Actions within this dimension support cities' ability to absorb CO_2, regulate temperature, and reduce the risk of extreme weather events (e.g., floods) through natural defence mechanisms such as blue-green infrastructure and nature-based solutions [120], [33]. It emphasises protecting biodiversity in cities, which is important not only for ecosystem health but also for residents' quality of life [101]. Green areas also play an important psychological role, promoting stress reduction, improved well-being, and mental regeneration for city residents. Increasing the number and improving the quality of urban green areas support local ecosystems and contribute to air and water purification [10].

The environmental dimension is closely associated with green infrastructure in cities, or more broadly, with blue-green infrastructure [62]. Blue-green infrastructure, understood as a network of natural and semi-natural spaces, positively influences urban resilience [87]. Green areas in cities primarily influence the hydrological cycle, reducing the risk of floods and droughts [40]. This dimension also plays a significant role in cooling cities. Green areas reduce the urban heat island effect by providing shading, increasing evaporation, and improving air circulation, thereby lowering temperatures in urban areas [81]. Urban resilience and adaptation to climate change are complementary strategies that help cities cope with climate uncertainty. In this dimension, protecting biodiversity and improving air and

water quality are also important [80]. Vegetation in cities filters air pollutants and supports stormwater purification, stimulating the development of urban resilience [48].

This dimension is a key element that enables cities to achieve sustainable development amid rapid societal and environmental transformations. These efforts require an interdisciplinary approach combining urban planning, environmental engineering, and social engagement. The environmental dimension of urban resilience and the natural environment enable the construction of cities that are more resilient to crises, particularly environmental ones. However, an integrated approach to planning, financing, and management is required to achieve long-term positive effects in the context of urban resilience [106].

5.4. Economic dimension

The economic dimension of the urban resilience concept refers to cities' ability to build resilience to threats and changes through actions that support economic stability and development [2]. It focuses on economic strategies that help cities withstand crises, mitigate financial losses, and stimulate long-term growth.

Urban resilience in its economic dimension encompasses actions that support the local economy, such as economic diversification [12]. Reducing dependence on a single industry helps cities cope better with economic crises, while economic monoculture lowers resilience [27]. Antifragility is also important: economically antifragile cities can not only withstand crises but also strengthen their development potential amid disruption and uncertainty. They can use crises to diversify their economies, develop innovation, strengthen local entrepreneurship networks, and increase the flexibility of the labour market and financial systems [110], [15]. A flood, for example, can severely affect a specific economic sector, reduce city budget revenues, and generate high rebuilding costs, delaying a return to the pre-disruption state [111]. Detroit illustrates this point: deindustrialisation and the collapse of the automotive industry led to population decline, a crisis in public finances, and bankruptcy [66].

The economic dimension also includes asset protection, which helps sustain economic activity and stable development. It involves securing public assets, such as infrastructure, public utilities, and transport networks, as well as private assets, including real estate, businesses, and productive capital, from climatic, technological, and economic shocks. Asset losses are among the main drivers of long-term local economic destabilisation [47].

Economic resilience also depends on investing in sectors and solutions that improve financial stability and reduce vulnerability to external shocks. Low-carbon infrastructure, including green buildings and public transport, can reduce energy costs and dependence on volatile commodity markets [16], [82]. These investments also bring indirect benefits, such as improved air quality and residents' health, which can reduce long-term public healthcare spending [81]. Cities that invest in sustainable infrastructure also become more competitive and attractive to investors. Creative industries also play a significant role: according to Richard Florida's creative class concept, they foster innovation, attract highly skilled specialists, and strengthen the local knowledge-based economy [37]. Greater investment attractiveness can attract private capital and external funds, which can be reinvested in further adaptation measures. In this way, investments in resilience strengthen local economic capital and improve environmental outcomes. The economic dimension of urban resilience is therefore becoming part of strategic development management, not only a response to crises. Sustainable investments, economic diversification, and reduced inequalities make cities more resilient to economic crises and support their long-term stability and competitiveness [1], [47].

5.5. Social dimension

The social dimension of urban resilience refers to the mechanisms and social resources that enable residents to function effectively during crises and recover quickly. The literature primarily emphasises the need to strengthen social well-being, build strong bonds and social capital, and ensure equal access to resources, services, and support mechanisms, all of which constitute the foundation of social justice [21], [4]. Therefore, a socially resilient city strives to create an inclusive environment that takes into account the needs of seniors, people with disabilities, and groups at risk of exclusion, minimising inequalities and enhancing the entire community's ability to respond collectively to crises [117], [102]. This means, among other things, providing accessible public infrastructure, developing care and healthcare services, and adapting crisis communication systems to the needs of various social groups, all of which are crucial for increasing the safety and well-being of residents. In addition, the involvement of residents in decision-making processes is crucial, strengthening a sense of agency and trust in public institutions and improving the community's adaptability to shocks. In this way, social capital is built, which in crisis situations constitutes a key resource enabling rapid mobilisation and solidarity-based action. A network of relationships, trust, and cooperation among residents therefore plays a key role in increasing social resilience [30].

Providing access to resources such as housing, education, and healthcare for residents, particularly those at risk of social exclusion reduces their vulnerability to threats and, in turn, positively influences social resilience [120]. In the context of creating socially resilient cities, raising awareness and educating residents about threats and mitigation strategies are also crucial [6], [72]. Examples include educational programmes in schools and local communities on climate change and coping with its effects, as well as information campaigns that support residents' preparedness for natural disasters, such as earthquakes [56].

Well-designed public spaces that incorporate green areas into the urban fabric not only promote improved mental health and reduce stress but also strengthen social bonds and social capital [54]. Research shows that the shared use of green spaces increases residents' trust and integration, which facilitates mobilisation and solidarity in crisis situations. Thus, biophilic urban design and the development of accessible green spaces are important elements in building social resilience, as they combine improved individual well-being with strengthened local community cohesion [59].

6. TOWARDS A GREEN URBAN RESILIENCE

The environmental dimension of the urban resilience concept was selected for further in-depth literature review, as it is fundamental to the functioning of urban systems and directly determines their capacity for adaptation, regeneration, and long-term development. The natural environment is a key element shaping urban resilience, and its role in the context of contemporary challenges continues to grow [105].

Green areas and natural resources not only mitigate the negative effects of climate change but also have impacts that extend across multiple dimensions of resilience [40]. Their influence extends beyond the environmental sphere to include improving social well-being, strengthening local ties, increasing the value of public spaces, and shaping investment attractiveness and urban aesthetics [89].

In the literature, there is growing interest in the environmental dimension of urban resilience. Both the number of publications and the broadening of thematic scope are evident, encompassing issues of ecological infrastructure, climate adaptation, ecosystem services, water management, and sustainable spatial planning [75]. At the same time, this area is characterised by a high degree of interdisciplinarity, integrating knowledge from environmental sciences, urban planning, geography, urban engineering, economics, and the social sciences [105]. This interdisciplinarity makes it a particularly valuable area

for bibliometric analyses, which allow for the identification of trends, dominant themes, and research gaps. The importance of the natural environment in cities is currently being reinterpreted. It is perceived not only as an aesthetic element but also as a key factor influencing quality of life and residents' health, as well as building resilience to climate change [3]. Greenery is increasingly integrated with urban infrastructure and treated as an essential component of sustainable development.

The choice of the environmental dimension for further bibliometric research is justified by its important role in building urban resilience, its broad impact on other resilience dimensions, and its growing prominence in scientific discourse on sustainable and resilient urban development. This focus will enable a better understanding of the relationship between the environment and the functioning and adaptability of urban systems, as well as the identification of key trends and future research directions.

6.1. Current Directions in Research on the Environmental Dimension of Urban Resilience

To identify thematic clusters, or subdimensions, of the environmental dimension of urban resilience, a network analysis was conducted using keyword co-occurrence analysis. This analysis identified four subdimensions discussed in the scientific literature on the environmental aspects of urban resilience: green infrastructure, climate change, spatial analysis, and urban planning.

The first subdimension, **"green infrastructure"**, focuses on concepts such as urban resilience, green infrastructure, urban sustainability, ecosystems, and biodiversity. It encompasses studies that consider resilience as an integrated effect of the functioning of environmental components in cities and emphasise the importance of green infrastructure in increasing adaptive capacity. The dominant themes here are ecosystem services, the role of urban greenery in disaster risk reduction, and the synergies between resilience and sustainable development.

The second subdimension, **"climate change"**, groups concepts related to climate change, urban heat island, air quality, sustainability, resilience, and urbanisation. Research in this area focuses on the impact of global climate change on urban environmental conditions and on ways to mitigate adverse phenomena such as heat islands and air quality degradation. The strong links between climate change and resilience are reflected in the growing number of publications highlighting the need to integrate climate adaptation into urban planning and policies grounded in urban resilience concepts. Greenery-based tools, such as green roofs and blue-green infrastructure, are also frequently analysed and assessed for their effectiveness under conditions of increasing climatic stress.

The third subdimension, **"spatial analyses"**, encompasses terms such as urban area, GIS, spatial analysis, cities, urban development, landscape, and population statistics. Its focus is clearly methodological – it examines the use of geoinformatics and spatial analyses to study urban resilience and the urbanisation processes that influence environmental functioning. This subdimension is dominated by empirical studies based on spatial data, often focusing on specific countries or regions (e.g., China, the USA). It also serves as a bridge between environmental analysis and urban policy research, enabling the identification of phenomena related to spatial resilience.

The fourth subdimension, **"urban planning"**, encompasses urban planning, green space, ecosystem services, urban design, and land use. It encompasses research on the role of spatial planning in creating conditions conducive to urban resilience. The focus is on the functional and spatial distribution of green spaces and their connection to various urban structures. Studies often utilise tools to assess ecosystem services and to model scenarios for changes in spatial development.

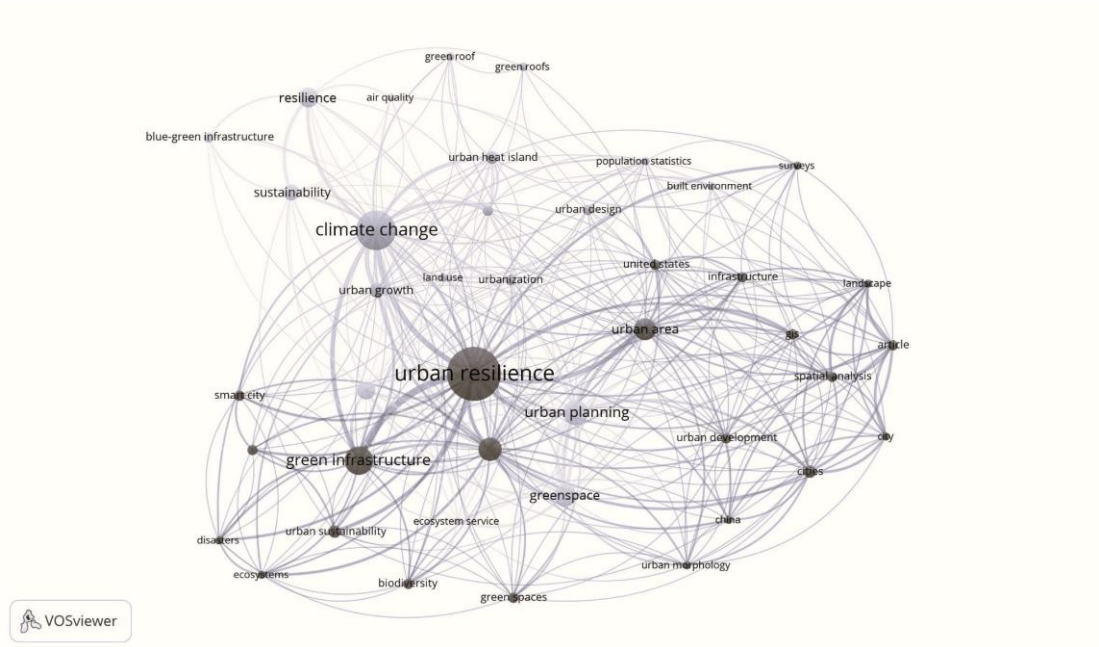


Fig. 3. Keyword co-occurrence network within the environmental dimension of urban resilience
Source: prepared based on Scopus and VOSviewer

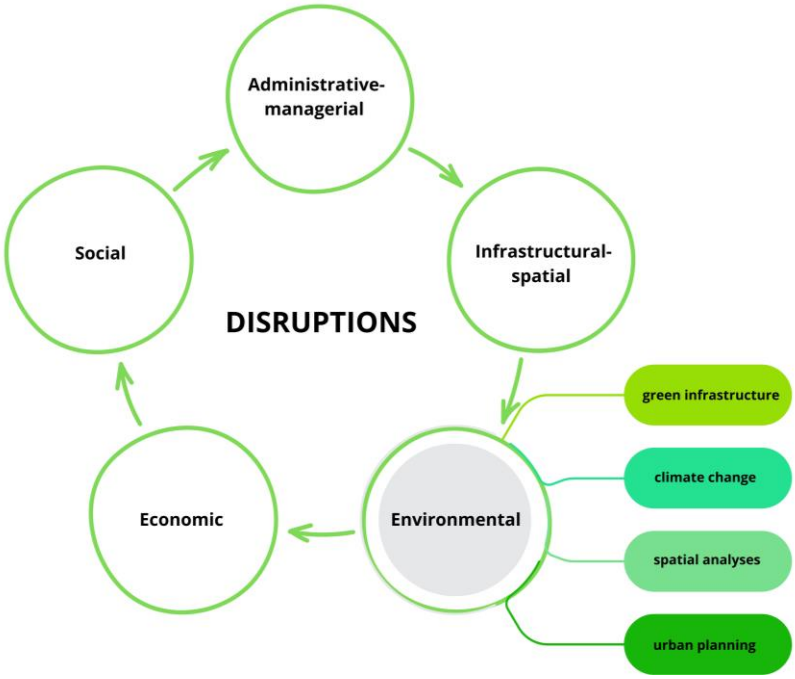


Fig. 4. Dimensions of urban resilience and subdimensions of the environmental dimension
Source: prepared by the author

Network analysis reveals strong interconnections between the four subdimensions, which together form a coherent knowledge system on the environmental dimension of urban resilience. Urban resilience is a key element that integrates the entire network, is situated at the centre of co-occurrence structures, and serves as a bridge between the other subdimensions. The green infrastructure subdimension remains strongly linked to the urban planning subdimension, reflecting the growing recognition that the design and management of urban spaces must increasingly rely on ecosystem mechanisms. At the same time, the climate change subdimension links resilience to environmental threats resulting from global trends. Spatial analyses enable the determination of the distribution of green infrastructure, the identification of areas vulnerable to climate risks, and the assessment of access to ecosystem services, making them a key approach for green resilience strategies. The relationships between the subdimensions clearly indicate that green urban resilience is emerging as a distinct research strand at the intersection of urban ecology, spatial planning, climate adaptation, and geoinformation. It is the coexistence of these domains that makes nature-based resilience a key direction for urban policies aimed at adaptation, risk reduction, and improvement in residents' quality of life.

6.2. Green urban resilience - an attempt at conceptualisation

The author's concept of green urban resilience is based on the four identified subdimensions of the environmental dimension. However, the remaining four dimensions are equally important and serve a complementary function, providing a broader context for this concept.

Green urban resilience expands the environmental dimension of urban resilience. It refers to a city's ability to absorb environmental pressures, adapt to them, and transform in response to them by drawing on natural resources and nature-based solutions. In light of the bibliometric analysis, it can be understood as an integrated system of activities, processes, and structures in which urban ecosystems and green infrastructure, along with their regulatory, supporting, and cultural functions, play a key role.

Green urban resilience emerges at the intersection of four main research areas: green infrastructure, climate change, spatial analysis, and urban planning. First, green infrastructure emphasises the importance of ecosystems and biodiversity as the foundation of a city's adaptive capacity, particularly by providing ecosystem services and mitigating the impacts of natural hazards. Second, green resilience is associated with mitigating and adapting to climate change, including reducing the urban heat island effect and improving air quality, often using solutions such as green roofs or blue-green infrastructure.

Another important component of green urban resilience is the infrastructural and spatial dimension, which enables the identification of areas exposed to environmental risks and the assessment of the availability and effectiveness of green infrastructure. Operationally, geoinformatics tools and spatial analyses provide the basis for making planning decisions. Finally, urban planning plays an operational role, integrating environmental elements with spatial development policies by appropriately shaping the structure of green areas and their functional connections.

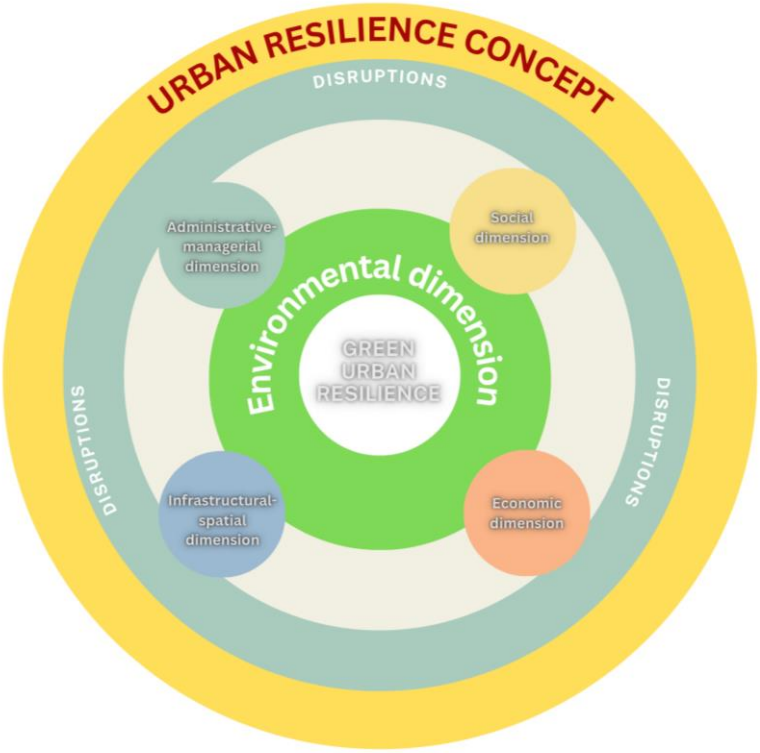


Fig. 5. Conceptual approach to green urban resilience
Source: prepared by the author

As a result, green urban resilience can be defined as the ability of an urban system to maintain and improve the quality of life of its inhabitants through the conscious use and enhancement of natural resources in planning, management, and adaptation processes. This holistic approach integrates ecological (green infrastructure), climatic (climate change), spatial (spatial analyses), and planning (urban planning) perspectives, positioning nature as a central factor in shaping the city's long-term stability and development.

The introduction of the original concept of "green urban resilience" represents a significant innovation in relation to the classical approach to urban resilience. While the traditional approach relies on a multidimensional assessment of the urban system's ability to absorb shocks, the proposed concept thoroughly operationalises and details the environmental dimension, redefining the role of natural structures. In green urban resilience, natural resources and blue-green infrastructure are no longer treated merely as supporting components or backdrops to urban development processes but rather as central and overarching elements. This stems from the fact that urban ecosystems and their functions (regulatory, supporting, and cultural) are defined here as the primary, autonomous foundation of a city's adaptive capacity. As a result, the transition from classical resilience to green resilience entails an evolution from the defensive protection of urban structures towards active, integrated urban management based on nature-based solutions.

7. DISCUSSION

Bibliometric analysis identifies research trends, conceptual structures, and thematic clusters across many phenomena. Its multidisciplinary nature and universality are used in numerous research fields. Applications include attempts to define key dimensions in education [124], current research in quantum physics [52], and the digital revolution in agriculture [11]. In each case, the analyses presented current research topics addressed in the phenomena under study.

The concept of urban resilience is increasingly analysed using bibliometric methods, which identify main research directions, collaboration networks, and the concept's evolution in the scientific literature. For example, Bautista-Puig et al. [9] conducted a bibliometric analysis of publications from the Web of Science database, focusing on links between urban resilience and sustainable development. Guo et al. [45] used bibliometric analysis to visualise the knowledge structure, map keywords, and identify the most important authors and research centres focusing on urban resilience. Kong et al. [58] presented a different approach, combining bibliometric analysis with visual analysis of research trends concerning the application of resilience theory in urban development. The authors analyse how urban resilience has developed, the main research directions, and the methods used to assess it. These studies use large databases and knowledge mapping tools but differ in scope. Some authors focus on the evolution of the concept and the structure of the discipline, while others focus on its relationship with sustainable development policy or its practical applications. A common feature is the pursuit of dominant themes, trends, and research gaps in the dynamically developing field of urban resilience [74], [78].

Polish researchers analyse urban resilience in the context of spatial planning, climate change adaptation, and urban development management, among other areas. Rogatka et al. [99], [100] focus on assessing the planning documents of the largest Polish cities and the extent to which urban resilience principles are implemented in spatial policy. Masik and Gajewski [70] examine the adaptive, absorptive, and transformative capacities of cities in the face of climate and socio-economic crises, emphasising strategic urban development management. Wereda et al. [115] analyse the role of ICT and the smart city concept in strengthening urban resilience, using survey research and quantitative methods. These studies share a systemic perception of the city as a complex social, environmental, and infrastructural structure. They differ mainly in research methods and scale of analysis. Some authors rely on strategic documents, while others use expert-based research or quantitative data on city functioning and digital tools [13], [22]. In the context of urban resilience, disruptions are sudden or long-term events that destabilise the functioning of the urban system. Meerow, Newell, and Stults [75] point out that urban resilience refers to a city's ability to maintain or quickly regain basic functions in the face of disruptions and to adapt to future threats. Holling [50], in developing the foundations of resilience theory, emphasised that disruptions play not only a destructive role but also stimulate processes of reorganisation and adaptation of socio-ecological systems. In urban resilience research, disruptions are therefore a key element in assessing cities' capacity to absorb crises, learn, and transform towards more sustainable development.

The identification of the disruption dimension in this study as a primary dimension in the context of urban resilience sharpens the approach proposed by Holling [50], in which disruptions were treated as a system element influencing the dynamics of its transformation. The previously mentioned taxonomies of urban resilience dimensions distinguished equivalent dimensions without a clear hierarchy of the role of disruptions. However, the network analysis indicates that disruptions serve as an axis that organises the relationships between dimensions. This makes the disruption dimension the central element, as it describes the nature of the pressure and the dynamics of the disruptions against which resilience is tested.

Based on their research on community resilience to disasters, Ostadtaghizadeh et al. [83] distinguished five dimensions of urban resilience: physical, natural, economic, institutional, and social. Ribeiro and Gonçalves [97] also conducted their own resilience analyses based on the aforementioned five dimensions. Delgado-Ramos and Guibrunet [26] identify four main dimensions of urban resilience: economic, ecological, socio-cultural, and governance. Kapucu et al. [55] present a different definition of these dimensions. They identify five main dimensions of urban resilience discussed in the scientific literature: environmental, infrastructural, economic, human, and institutional. These researchers define the dimensions of urban resilience in different ways and from different perspectives. Determining the dimensions of urban resilience depends on the adopted methodology and research approach. The dimensions identified in this study administrative-managerial, infrastructural-spatial, environmental, economic, and social confirm both the complexity of the issue under study and the multidimensionality of the concept. A different approach was presented by Yabe, Rao, and Ukkusuri [118], who analysed urban resilience through the interdependencies between a city's social and physical systems. The authors do not develop a classic multidimensional typology of urban resilience; instead, they focus on the relationships between local communities and critical infrastructure during recovery from natural disasters. This approach differs from previously presented taxonomies because it reduces the analysis to key functional relationships influencing the urban regeneration process, rather than distinguishing a broad catalogue of equivalent dimensions of the concept.

The networked connections within the environmental dimension between categories such as green infrastructure and climate change indicate a progressive ecological reinterpretation of urban resilience. This convergence is strongly supported by the literature. Zuniga-Teran et al. [123] emphasise that green infrastructure is a key component of resilience by reducing flood risk, mitigating the urban heat island effect, and improving air quality, among other benefits. Grimm [44], in turn, points out that cities function as complex systems whose stability depends on the quality of the relationship between the natural and social components. An ecological reinterpretation of urban resilience suggests that cities are socio-ecological systems, and resilience should be studied not only as the physical ability to return to a pre-disturbance state but also as the relationships among individual systems (or subsystems) within the city. As Ernston et al. [34] point out, however, urban ecosystems are crucial in this respect, serving as catalysts for urban resilience.

Green urban resilience is distinct from related concepts in the literature. Ecological resilience primarily addresses the resilience of ecosystems, while climate resilience concerns the capacity to adapt to climate change. Nature-based solutions and green infrastructure refer to interventions that employ natural processes and multifunctional green infrastructure elements [73], [38]. The present conceptualisation of green urban resilience does not supplant these approaches but rather integrates them within a broader urban resilience framework, positioning the natural environment as a co-creator of the urban system's capacity to respond to disturbances and adapt over the long term [73]. The proposed analytical framework aims to clarify the role of the natural environment within urban resilience and to delineate its connections with other dimensions of the concept.

7.1. Limitations of the study

This study presents methodological limitations that inform directions for future research. The selection of Scopus as the primary source of bibliographic data was based on the large number of publications on urban resilience, its broad journal coverage, unified metadata structure, and compatibility with VOSviewer software, which is widely used in bibliometric analyses [112], [29]. Scopus is among the most frequently utilised databases in bibliometric studies, facilitating comparability with previous research findings [7], [29]. However, reliance on a single bibliographic database may limit the scope of

the analysed research material, as databases vary in journal coverage and selection policies. The simultaneous use of multiple databases could potentially identify additional publications, though it is unlikely to fundamentally alter the main trends and thematic structures observed in this study.

Another limitation concerns the use of keyword co-occurrence analysis. While this method effectively identifies dominant research directions and relationships between topics, its results are influenced by the selection of keywords by publication authors and the indexing principles of the database [29]. Nevertheless, keyword co-occurrence remains a widely adopted and well-established approach in bibliometric research. The analysis was based on the primary search phrase "urban resilience," which is the predominant term in the scientific literature. Some relevant publications may employ alternative terms, such as climate resilience or urban adaptation. Expanding the search strategy to include additional phrases represents a promising direction for future research.

Despite these limitations, the research procedure enabled a comprehensive identification of contemporary research directions in urban resilience. It facilitated the development of a systematic conceptual framework that organises the main dimensions of this concept. Future studies could benefit from incorporating additional bibliographic databases and employing complementary bibliometric techniques, such as co-citation analysis, to provide a more comprehensive depiction of the evolution of urban resilience research.

8. SUMMARY AND CONCLUSIONS

The literature review and bibliometric analysis enabled the systematisation of research on urban resilience by identifying five dimensions: administrative-managerial, infrastructural-spatial, environmental, economic, and social. Furthermore, a significant contribution of this study to urban resilience research is the identification of the disruption dimension as the overarching dimension linking the other dimensions. This dimension does not function as a parallel analytical category but as a set of primary determinants, i.e., various disturbances that initiate the need for adaptation and organise the relationships between the other dimensions. This means that urban resilience should be interpreted not as a static equilibrium state but as a dynamic response of the urban system to disturbances, which determines the directions of further action.

However, keyword analysis indicates a clear asymmetry in how these areas are represented in the literature. The most frequently studied dimensions of urban resilience are administrative-managerial and infrastructural-spatial, reflecting researchers' growing interest in adaptive spatial planning, crisis management, and the technical aspects of urban resilience. The study also shows a relatively low representation of the social and economic dimensions in urban resilience research. The insufficient consideration of economic factors suggests the need for future research into the resilience of urban financial systems and the mechanisms that ensure their long-term stability amid crises. The social dimension of urban resilience should become a leading theme in research in the near future.

The environmental dimension is gaining particular importance in the discourse on urban resilience. In-depth bibliometric analysis reveals dynamic thematic developments, from which four dominant subdimensions emerge: green infrastructure, climate change, spatial analysis, and urban planning, confirming the growing greenisation of resilience discourse. At the same time, despite the increasing number of environmental publications, this dimension does not dominate the overall structure of the reviewed literature, giving way to administrative-managerial, and infrastructural-spatial issues. This indicates the need for further integration of the environmental component into mainstream urban resilience research. The study also operationalised the concept of green urban resilience as the ability of an urban system to absorb disruptions, adapt to them, and transform in response to them by leveraging natural resources, green infrastructure, and nature-based solutions. It encompasses the integration of

ecological, climatic, spatial, and planning aspects to mitigate environmental risks, strengthen the city's adaptive capacity, and maintain residents' quality of life.

The results of the analyses indicate that the concept of urban resilience is evolving toward a more multidimensional approach to city functioning, taking into account managerial, infrastructural, social, and environmental aspects. At the same time, the study indicates the need for further research on the relationships between the individual dimensions of resilience and on the role of disruption as a factor determining the adaptation processes of contemporary urban systems.

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