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Abilities and limitations in counteracting urban heat islands

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Abstract: The article presents observational and simulation trends that have been used to mitigate the urban heat island phenomenon. Due to extensive progress in computing, researchers have focused on methods based on artificial intelligence. AI offers significant potential in counteracting UHIs through rapid temperature prediction, high-resolution mapping, optimisation of green spaces, and decision support. While AI models can expedite predictions, their precision may still lag behind traditional numerical weather prediction methods. The presented tools have major limitations, including the complexity of applying artificial intelligence to process the large datasets generated during city operations. The article presents the advantages of using AI algorithms to mitigate urban heat islands, which include more efficient management of energy, heating, and water infrastructure, as well as support in urban analysis. The ability to process vast amounts of data allows for more effective use of energy and water resources in buildings while continuously improving the algorithm. The literature review involved a comparison of current methods used to counteract urban heat islands, as well as existing and potential applications of artificial intelligence algorithms described in the Scopus and Web of Science databases. The analysis included the classification of the main groups of AI algorithms, their capabilities and limitations in mitigating urban heat islands, and an overview of the main trends in contemporary scientific articles on the use of AI in architecture. The selection criteria for the literature included the publication period (2016–2024), the applicability of the described solutions, and the current limitations and disadvantages of their use. The article highlights the main challenges in the widespread adoption of artificial intelligence in architecture.

Keywords: urban heat islands, artificial intelligence, machine learning, architecture and urban planning

1. Introduction

Understanding the process and mechanisms underlying the impact of urbanisation on urban warming is essential for future urban planning and development. This implies the need to develop tools and strategies to mitigate the negative effects of climate change [1]. One of the modern tools used in architectural planning, construction, and energy management is artificial intelligence algorithms. The large number of scientific articles concerning the potential applications of AI algorithms in architecture, construction, energy, and urban infrastructure management highlights the need to systematise knowledge in this area. The aim of this article is to compare the possibilities and limitations of mitigating the negative effects of urban heat islands (UHI) using conventional methods versus the application of artificial intelligence algorithms and techniques. Additionally, the article seeks to define the scope of applicability of algorithms useful in combating urban heat islands and to outline the direction of future development in this scientific field. The article also presents the scope of applicability of individual artificial intelligence algorithms and the development trend in this field of science. These solutions have been divided in terms of short-term and long-term effects. An additional criterion for dividing these solutions is their nature: architectural and urban, simulation and computational. Systematising the existing body of knowledge in this area will help to identify the most effective strategies to improve urban microclimates against the background of modern artificial intelligence algorithms.

1.1. Urban heat islands – observations and impacts

Population growth is a key driver of urbanisation [2]. Urbanisation, in turn, contributes to the physical development of urban areas and the formation of mega-cities, leading to the concentration of large numbers of people in small areas [3]. [4-5] examine the impact of urban development and climate change on UHIs and heat stress in the city. It is noted that considering the combined effects of urban development and climate change is crucial to understanding how temperatures in urban areas will change in the future.

The implementation of urban spatial policy shapes urban development on a city-wide scale. Instruments for the development of urban form in cities involve multidimensional and complex transformations. Understanding the typical characteristics of cities and the ways they differ from each other is crucial in mitigating the negative effects of UHIs [6-8].

In a street canyon, the temperature is slightly higher due to trapped solar radiation and restricted airflow [9].

The inexorable urban development is consuming huge amounts of soil, drastically reducing natural vegetation and replacing it with buildings and surfaces with a low albedo.

The study documents a negative correlation between vegetation and LST. As the built-up area expands and vegetation shrinks, LST will continue to rise. A surface urban heat island (SUHI) is defined as an increased land surface temperature (LST) in urban areas compared to non-urban areas, with a possible effect on energy consumption, comfort, and health of urban dwellers [10-13].

[14-16] have demonstrated that different IS materials have a statistically significant effect on mean LST.

UHIs have also been shown to affect the daily lives of urban dwellers by boosting household energy consumption for cooling and disrupting activities such as working and sleeping, as well as general health and well-being [17]. Studies have demonstrated increased health risks for urban dwellers compared to rural or peri-urban populations during hot weather and a disproportionate impact on vulnerable social groups [18].

The findings of [19] suggest that Physiologically Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI), and Wet Bulb Globe Temperature (WBGT) are the most widely used metrics in outdoor thermal comfort studies. [20-21] outline the impact of heat islands on air pollution and health impairment.

The reported impacts of UHI have shown strong inter-urban variation, with an increase in cooling energy consumption from 10% to 120% and a decrease in heating energy consumption from 3% to 45%. The UHI impacts have also shown clear variation within cities, with effects being stronger in city centres than in the urban periphery.

[22] describes Sydney, Australia, as a case study of an urban heat island. A correlation has been found between local overheating of highly urbanised areas and a reduced efficiency of photovoltaic systems by up to 11%.

UHIs contribute to increased pollution, leading to a reduction in solar energy absorption and an increase in pathogenic bacteria in urban air [23-25]. [25] has demonstrated that concentrated hazardous gas emissions from industry, energy, and transport in UHIs produce air pollution, affecting human health and resulting in respiratory issues, heat stress, and increased mortality. UHIs accelerate smog formation, leading to increased concentrations of harmful substances in the air, including greenhouse gases and ozone precursors [26]. Urban heat islands raise growing concern over the increased use of air conditioning. The needs of urban dwellers for thermal comfort exacerbate air pollution and greenhouse gas emissions [27].

The increase in air pollution due to UHIs affects the thermal regime and leads to the deterioration of surface water quality [15,28]. [29] demonstrates that water bodies in urban areas can have both a positive cooling effect and unanticipated consequences, such as increased concentrations of pollutants at street level, potentially aggravating the effects on human health and contributing to water pollution.

The negative effects of urban heat islands, as mentioned, can be mitigated using conventional methods; however, these methods are limited in terms of efficient energy and urban infrastructure management. Another challenge lies in the time required to process large volumes of data and the effectiveness of decision-making processes. In this context, the use of artificial intelligence algorithms becomes justified, as they can positively impact the efficiency of efforts to counteract urban heat islands.

1.2. Artificial intelligence in counteracting urban heat islands.

Artificial intelligence algorithms have the ability to rapidly process large volumes of data and determine optimal solutions to complex decision-making problems. These advantages enable the use of selected AI techniques and models in efforts to mitigate urban heat islands [30]. The nature of each method allows for the classification of their primary areas of application within architectural processes.

To directly and indirectly counteract urban heat island phenomena, AI algorithms can be applied in areas such as: crisis management, energy and water resource management, urban infrastructure management (e.g., road networks, stormwater systems, traffic intensity), and the production of electricity, heating, and cooling.

An equally important aspect of implementing AI in these cases is ensuring an adequate level of algorithm security against cyberattacks. To address such risks, an artificial intelligence model has been developed to prevent cyberattacks, as discussed in [31], detecting 90.6% of threats in up to 14 ms.

In terms of crisis management, it is beneficial to use techniques based on machine learning, as suggested in [31-33]. The aforementioned approach can be widely applied to urban emergency management, management of land route and waterway passability, fire management, and the prevention of overheating and excessive dust in cities. [34], among other studies, provides an example of predicting PM 2.5 dust well in advance using machine learning.

Another example of the use of improved, surface-based artificial intelligence algorithms is discussed in paper [35]: the algorithms have been used to manage the capacity of water reservoirs and the capacity of canals on the Yangtze River. The paper identifies refinements made to the algorithm compared to the conventional methods, including back-propagation of error in most cases. [36] describes other significant uses of artificial intelligence algorithms. They manage the operation of electric cars and their energy resources, which, in terms of the operation of urban agglomerations and their potential overheating, is a factor of indirect influence.

For resource management, ready-made algorithms specifically dedicated to buildings are also used – algorithms that simultaneously manage energy, waste, recycling, and the production of energy from renewable sources. [37] presents an artificial intelligence solution for intelligent buildings and intelligent monitoring systems with a higher computational accuracy compared to alternatives.

Another important aspect of using artificial intelligence models in urban infrastructure management may be the use of digital twins to better understand and improve the algorithm of things. [38] outlines the benefits and potential of this approach in the context of the design and control of smart city rainwater infrastructure systems.

The implementation of artificial intelligence in various aspects of cities is obviously hindered by various barriers. [39] describes the key constraints involved, such as technology, environmental, and organisational considerations. [40] provides an example of a complex analysis of buildings in terms of their impact on the indoor and outdoor environment, using fuzzy data envelopes and artificial intelligence algorithms. It has resulted in a significant reduction in energy consumption for cooling rooms in warm climates and CO_2 emissions of a building.

The examples discussed above can directly and indirectly impact the reduction of urban heat island (UHI) phenomena, among other things, by reducing the demand for heating and cooling in buildings through more efficient management. The current level of AI technology leads to limitations in the justified application of specific AI methods. Additionally, the authors have noted the main trends in the development and implementation of AI methods in architecture, which directly and indirectly influence the reduction of UHI.

2. Methods

This study focuses on organising knowledge and responding to questions on how to counteract and mitigate the problem of urban heat islands. The main research gaps considered in this work concern the clarification of contemporary possibilities and limitations in counteracting the urban heat island phenomenon, using both conventional techniques and artificial intelligence. This paper indicates limitations in the use of each method, along with specifying their advantages and disadvantages. Further in the study, the authors seek to integrate various data sources by considering the specific nature of the broad problem of climate change within urban structures and the potential solutions in the context of today’s opportunities for the use of artificial intelligence.

A detailed graphic diagram of the article structure is provided in Fig. 1.

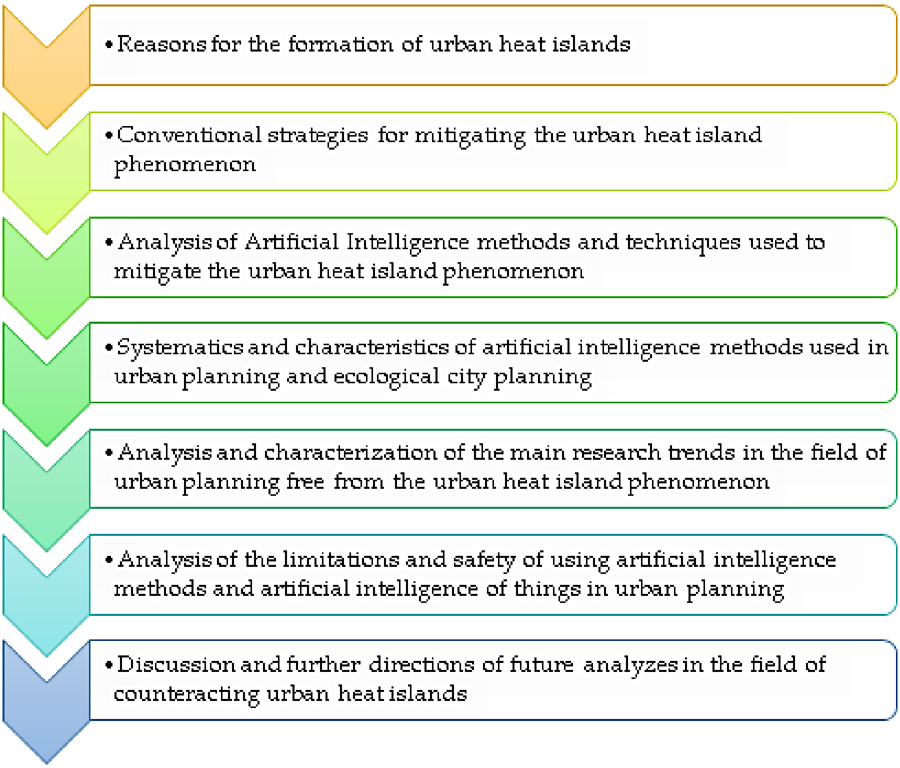

Fig. 1. Diagram of the article structure

The literature review was conducted based on the Web of Science and Scopus databases, focusing on scientific publications related to conventional methods for mitigating urban heat islands and the use of AI algorithms. The review included an analysis of 460 peer-reviewed articles published between 2016 and 2024. The articles were selected from search results using the keywords: "Urban Heat Islands, Artificial Intelligence, Internet of Things, and Heat Islands." Following a thorough analysis, 96 publications were chosen that most accurately describe the potential applications of AI algorithms in architecture and could contribute to reducing the phenomenon of urban heat islands.

3. Results

3.1. UHIs – mitigation strategies

The Sky View Factor (SVF) is a term used to quantify the amount of the sky visible from a specific point on the Earth's surface. It measures how much of the sky can be seen from a particular location, which can be influenced by surrounding structures, topography, vegetation, and other factors. In architecture, SVF is considered in the design of buildings and landscapes to optimise natural light, minimise heat accumulation, and improve ventilation. In places where buildings and other structures obstruct the sky, there can be less cooling from the sky, leading to higher local temperatures.

The SVF can be calculated using a variety of methods, including fish-eye imagery methods, 3D GIS methods, GPS methods, and street image methods. Calculating the SVF based on Street View images has advantages such as widely available data, low cost, and high efficiency. By calculating the SVF on a large scale, it is possible to gain insight into the zonal effect of UHIs [41-42].

Planning decisions to modify urban structure should be preceded by analyses of the effects of building geometry and orientation on radiation, temperature, and wind flow characteristics. The interaction between the shaded and sunny parts of canyons and between the cooler green squares and the warmer built-up areas plays a vital role in the energy balance of urban space. The geometry of street canyons, including building height, density, proportion of sky and vegetation, and the skyline, plays a crucial role in mitigating the urban heat island effect. On streets with low building height and density, the proportion of sky and vegetation is relatively high and the skyline is relatively flat, an arrangement that helps to mitigate the heat island effect. On streets with higher building height and density, the proportion of sky and vegetation should be lower, with the skyline proportionate and not too smooth or jagged. In construction, controlling the proportion of trees at the street interface and geometric shape can adjust the geometry of a street canyon at little cost, thus providing different cooling effects [43-45].

The calculations show that the higher the building is and the further away from the road it is, the higher the urban heat island intensity [46]. The findings of [47] show that the higher the ratio of distance between buildings, the lower the average canyon temperature. Avoiding uniform building heights and canyon widths and lengths improves the ventilation of urban streets [48]. Examples of the described design solutions to reduce the UHI effect are shown in Fig. 2.

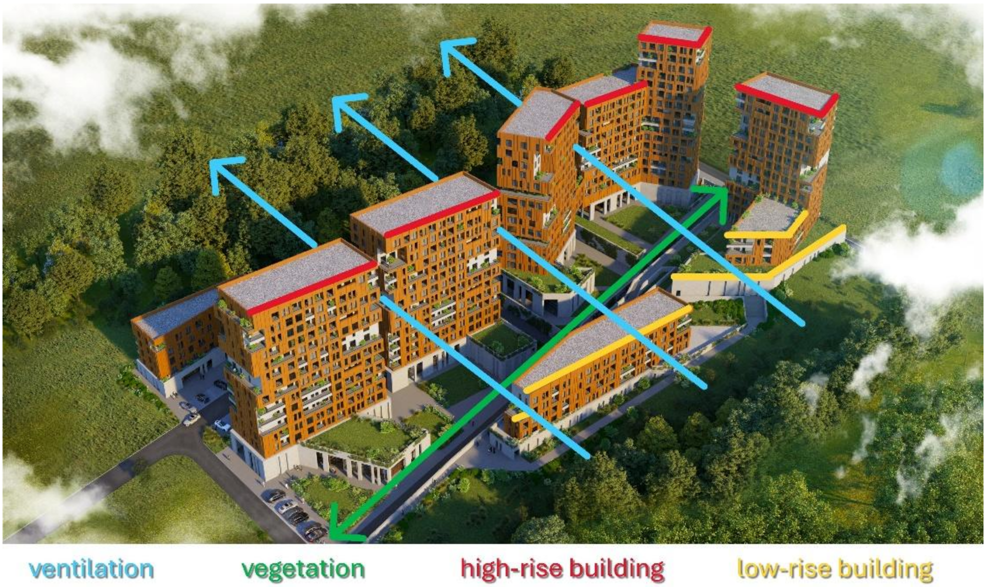

Fig. 2. Example of varying building heights to counteract urban heat islands. (Graphics made by S.T. Architekci)

Studies show that UHI max increases with an increasing building height/distance between buildings ratio, but urban canyons characterised by higher roughness (larger façade areas and more heterogeneous heights, $Zo \geq 2.0$) give UHI max values about twice as low as canyons characterised by lower roughness (homogeneous with the highest average building footprint, $Zo < 2.0$) for the same value of the building height/distance between buildings ratio [4].

It is recommended to combine blue and green structures, especially when space for their installation is limited. This application is exemplified by the external surfaces of buildings, which offer ample space for vegetation. Planting vegetation on roofs and walls has become one of the most innovative ways to provide a range of environmental services [49-52].

[53-54] discuss an experimental approach to solving the problem of urban heat islands, involving the use of reflective surfaces, additional greenery, an increased rate of evapotranspiration, along with a combination of these methods. The results presented in [53] show that the combined use of all measures counteracting the phenomenon can result in a 2.9°C reduction in maximum temperatures while reducing electricity demand by 1.5 TWh across the city.

[55] asserts the importance of parks and green spaces for improving physical and mental health, supporting biodiversity, absorbing floodwaters, improving air quality, and mitigating the urban heat island effect. Green infrastructure, such as urban gardens or natural areas, constitutes a significant part of the urban landscape. [56] highlights the layout of blue and green infrastructure in the urban fabric. Smaller and more dispersed spaces (green or blue) that make use of dominant wind patterns tend to provide a greater cooling effect over a larger area than a single larger urban planning scheme. Figure 3 shows a scenario for planning urban parks and greening street canyons. The cooling strategies referenced in [57] show that planting tall trees to shade pavements and introducing a variety of lower vegetation that absorbs air pollutants help to actively reduce ambient temperatures. The findings indicate that local climatic conditions have a significant impact on the cooling effect of urban greenery. [58] has demonstrated the existence of a local cooling effect arising from the conversion of vacant lots into green spaces.

[59-60] note that water bodies such as rivers, streams, and lakes play an important role in regulating the urban climate. Due to their high evapotranspiration rates, they are relatively more efficient than green spaces. One example of a good quality open space is New York's Central Park, shown in Fig. 4.

[61] describes the properties of reflective materials in terms of the directional dependence of solar reflectance, which allows solar radiation to be reflected back in the same direction as the incident solar radiation. In this case, the surface temperature in an urban interior should have lower values compared to an interior made of ordinary building materials.

Last but not least, the local overheating of urbanised city structures is determined by the albedo of their surfaces, as suggested in [62]. The low albedo of urban materials contributes to higher values of solar energy absorption and land surface temperature [63]. This factor, as stated in [61-65], results in an increase of up to 200 W/m² in the dissipation density of heat stored during a heatwave, which is four times higher than for savannah areas. One example of how to counteract heat islands is the use of cool pavement elements, which are characterised by greater solar reflectivity. In [66], cool pavements are found to reduce peak daily temperatures in the range of 4–20°C.

The analyses of insolation time and shading time of urban structures shown in Fig. 5 indicate different degrees of exposure of streetscape elements to solar radiation. This study allows the proper adjustment of streetscape and façade materials in terms of their reflectivity.

Fig. 3. Urban park planning scenario and greening of street canyons (Graphics made by S.T. Architekci)

Fig. 4. Central Park. New York, (Photography by Paweł Pyzik)

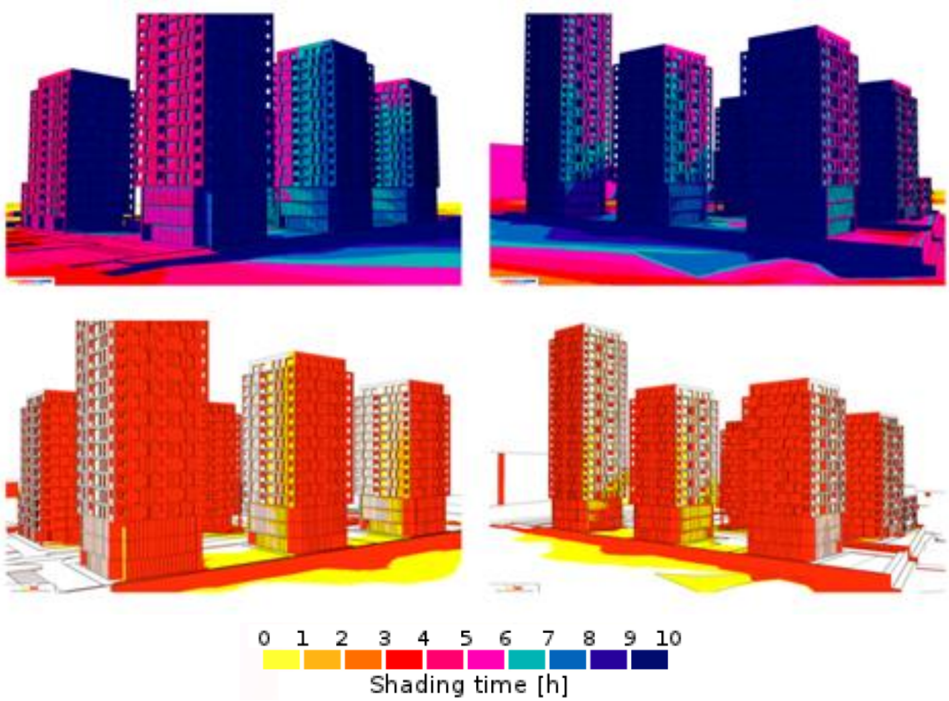

Fig. 5. Analysis of insolation and shading times of urban structures (Graphics made by S.T. Architekci)

Another solution to counteract the overheating of urban interiors is to ensure more efficient management and generation of energy from renewable sources, as discussed in [67-68]. This is an important issue, considering that, as suggested in [68], the increase in cooling demand of urban buildings in warm and dry climates is as much as 17% higher than in non-urbanised areas.

The example described in [69] demonstrates that the phenomenon of urban heat islands in spring and autumn in moderate climates can play a short-term positive role in lowering the heat demand of buildings. In order to enhance the efficiency of this phenomenon, it is necessary, however, to use green belts with a higher thermal inertia for storing the absorbed heat.

3.2. Artificial intelligence algorithms and trends in urban planning applications

The capabilities of the individual AI techniques and models outlined above can significantly reduce the occurrence of urban heat islands by selecting appropriate algorithms and connecting them to devices responding with action in real time. This will be possible thanks to more effective management of energy resources, heat, and technological cooling for heating and cooling buildings. The taxonomy of the most commonly used groups of artificial intelligence algorithms is presented in Table 1.

Table 1. Artificial intelligence algorithms and methods used in architecture and construction

Artificial Intelligence Models and Algorithms			source
AI and AI of thinks	Machine Learning	Adaptive neuro-fuzzy inference system (ANFIS)	[70]
		Convolutional neural networks (CNNs)	[72]
		Bayesian Networks (BN)	[74]
		Random Forests (RF)	[75]
		Decision Trees (DT)	[72]
		Linear regression (LR)	[76]
		Support vector machine (SVM)	[77]
		Generative adverarial networks (GANs)	[67]
	Deep learning	Genetic algorithm (GA)	[73]
		Batch normalization (BN)	[71]
		Artificial neural Network (ANN)	[78]
Natural language processing (NLP)	Machine Learning	Information and communication technologies (ICT)	[69]
Models	Deep learning	Natural Computing (NC)	[67,68]
		Computer Vision (CV)	[79]
		Evolutionary computing (EC)	[79]
	Machine Learning	Fuzzy logic (FL)	[67,79]
		Machine lerning (ML)	[67,68]

3.2.1. Main trends in the application of artificial intelligence in urban planning

One of the objectives of this article has been to identify the main trends in studies and reviews on the application of artificial intelligence algorithms in solving the problem of urban heat islands by reviewing the existing body of knowledge shared in reputable scientific journals from 2010–2024. A noticeable trend is a large number of papers presenting case studies of urban tissues [80-84], papers on management and detection of energy and matter resources [85-86], climate change mitigation [72,87,88], ecological transport [71,89-91], and ecosystem protection [92-94]. The largest group of papers concerns case studies in urban, ecological, and machine learning contexts. This is followed by papers on resource management and detection, and climate change mitigation. A graphical scheme of the breakdown of individual papers by number and subject matter category following the literature review is presented in Fig. 6.

In addition, the analysis of a number of scholarly papers on the application of artificial intelligence in architecture and urban planning has revealed an almost geometric increase in the number of published scholarly studies on this subject matter in the renowned Scopus database between 2016 and 2024. Information on the number of published papers has been obtained in the form of results from searches in the Scopus and ScienceDirect databases for the following phrases: "Urban heat islands, Artificial intelligence and heat islands". A summary of the number of published scholarly papers on the application of artificial intelligence in counteracting urban heat islands is provided in Fig. 7.

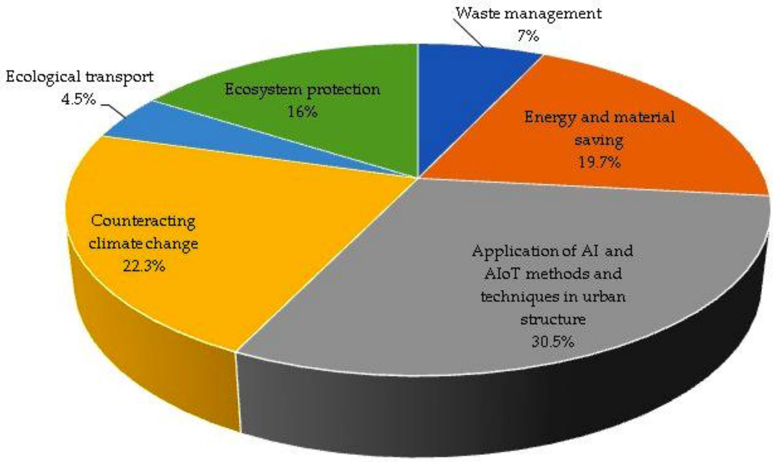

Fig. 6. A graphical breakdown of studies in the field of counteracting urban heat islands by subject matter and type

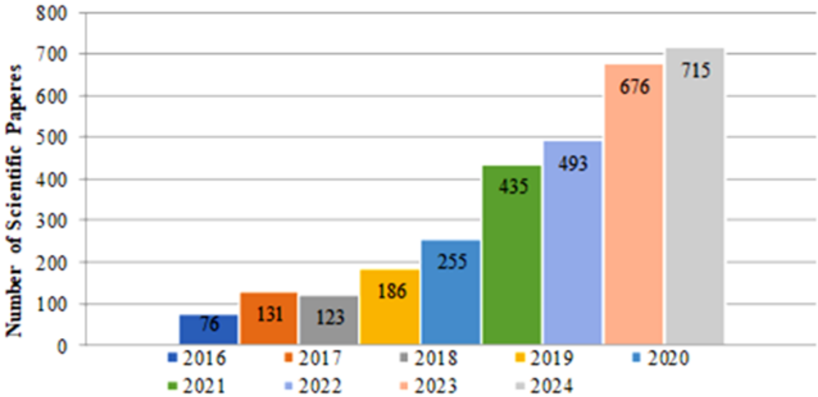

Fig. 7. A summary of the number of scholarly papers on the application of artificial intelligence in the context of counteracting and mitigating urban heat islands

3.2.2. Safety and potential risks associated with the widespread use of AI and AIoT

The application of artificial intelligence today faces significant challenges in terms of ethics, security, and privacy. In addition to the technological challenges, these are some of the most significant aspects that determine the feasibility and extent of the application of artificial intelligence to process the large data sets generated in the operation of cities.

According to [73], considering the challenges and limitations of applying artificial intelligence, it will not be possible in the future to obtain algorithms capable of simultaneously generating and processing wide ranges of data in real time. This suggests that real-time recording and processing of data with limited content is possible. It is therefore beneficial and expected in the context of applying artificial intelligence in city structures to counteract the temporary and medium-term overheating of these structures.

The increase in the use of AI [95] describing the aspect of counteracting UHI was 73% in relation to applications in the field of transport engineering, health care, and water, energy, and waste management. About 34–76% of the data is not fully used in the functioning of AIoT [31]. Moreover, another limitation to the general use of AI in the context of its broad application is the expected significant increase in the energy demand needed to power it. The energy demand of AI and AIoT devices is estimated to increase from the current 1% to a total of 20% of global energy demand [31].

Another equally significant challenge, related to security and privacy, lies in the issues described in studies [76-78] regarding the implementation of the concept of "smarter eco-cities" as techniques capable not only of processing data and suggesting responses, but also of deciding for themselves. In this context, areas related to Explainable Artificial Intelligence (XAI) require significant development. The ability to delve into the decision-making structure of an algorithm eliminates the widespread use of techniques based on the concept of "black boxes". Considering and at least partially solving the aforementioned limitations will allow for a more effective use of AI capabilities in optimising and managing the operation of cities.

4. Discussion

As part of the discussion related to the analysis of trends in the development of artificial intelligence techniques and their implementation to solve the problem of urban heat islands, the focus was on a detailed description of their capabilities.

The analysis of the body of knowledge on the application of artificial intelligence algorithms in the context of urban heat islands has led to the following general conclusions: ICT systems make it possible to manage telecommunications and electro-energy infrastructures by adapting the amount of energy produced to anticipated demand. The need to extend these capabilities to include CV and FL algorithms will further allow for efficient urban traffic management as well as resource and waste management. This will allow for more effective reductions in energy and matter consumption and reductions in dust emissions and fossil fuel combustion products.

The widespread use of AIoT techniques and Big Data technologies makes it possible to achieve at least part of the eco-city and smart-city objectives; this, as noted in [76-96], has been the case since 2015–2016. This has enabled the processing of huge volumes of data over a short period of time while simultaneously making more efficient use of learning data. Furthermore, this has enabled the construction of more complex algorithms to better describe the mapped reality.

A decisive aspect of the success of AI applications in urban resource management is their proper implementation and the monitoring of their performance. In this context, pilot programmes [97] are important. [97] identifies the assumptions of pilot activities showing how regions can change the way they address climate change in the spatial structure of cities. The findings of research into pilot activities show a major shortage of skills, knowledge, and training related to the implementation of systemic solutions for planning and deploying breakthrough low-carbon technologies in a built-up environment. The use of AIoT techniques will allow cities to understand which solutions are effective, in what context, for whom, and why. Moreover, the process will involve gathering knowledge about the scalability and replicability of solutions.

The next step in the more effective implementation of artificial intelligence in urban structures is a wider use of blockchain technology. As discussed in [70,74,75], blockchain technology enables the decentralised processing of extensive data sets and the implication of other AI algorithms. This approach optimises computational resources and is aligned with the theory of the next generation of district heating and energy systems, which are also designed to be network-based and decentralised by default.

Some of the limitations in applying AI and AIoT techniques today include inadequate keyword selection, which does not accurately reproduce the content of a command. In addition, the nature of individual algorithms is a limitation in itself, especially when addressing complex real-time problems. The extent of applicability involves an indeterminate level of error due to the fact that many authors publish the results of research and studies that have been at least partially successful, omitting a number of trials and tests ending in failure. This is why one should assume limited confidence in the published claims regarding the widespread and almost unlimited use of AI algorithms in urban planning.

Among today's trends witnessed by the authors of this study, the undeniable advantages and benefits of AI and AIoT techniques and algorithms lead to a significant transformation of previous perceptions of reality and ways of solving problems. Against this background, AI and AIoT represent a well-suited tool to address the problem of urban heat islands, by managing resources in a more efficient manner and by indirectly influencing human behaviour and habits.

An undoubted limitation in quantifying the potential benefits of using AI or AIoT algorithms is the limitation of the scale of research sites. For this reason, numerical benefits can be determined in comparison to past conditions with similar input parameters or as a result of the verification of many different computational models operating on the basis of different algorithms.

In summary, the development of AI and AIoT technologies to address urban heat islands should focus on creating adaptive, context-aware systems that integrate seamlessly with urban infrastructure. This requires a balance between cutting-edge technology and the practical realities of urban living, ensuring that AI systems are inclusive, ethical, and effective in addressing local needs. Future AI models should be designed with scalability, flexibility, and real-time response capabilities in mind, ensuring they evolve as urban environments grow and change. Finally, pilot programmes and ongoing collaboration with urban planners, citizens, and policymakers will be crucial to successfully leveraging AI in building more sustainable and liveable cities.

5. Conclusions

Processes of adaptation to climate change focus mainly on measures to reduce risks resulting from anthropogenic activities. Adapting the geometry and orientation of buildings and matching the reflectivity of materials to local climatic conditions have a relevant impact on high daily temperature amplitudes and wind flow.

The implementation of blue-green infrastructure increases the interaction between cooler green squares and warmer built-up areas, which plays a very important role in the distribution of heat in urban space. Efficient energy management and generation from renewable sources counteracts the overheating of urban interiors.

Artificial intelligence algorithms allow for more efficient management of energy resources and urban infrastructure, and can predict the likelihood of crisis situations occurring in cities. A major limitation in using AI to mitigate UHI is integrating various algorithms in such a way that they can process vast amounts of data in real time, while also providing real-time responses.

In addition, in situations where it is not possible to give an unambiguous answer due to the nature of the phenomenon, FL algorithms allow the estimation of the probability of occurrence of the phenomenon, which is particularly necessary during crises, e.g., fires, floods, hurricanes, and environmental contamination. In the context of securing the thermal performance of entire cities, there are not yet any tools that fully allow for the holistic management of urban resources in real time.

Moreover, in the context of energy security, the amount of energy necessary to power devices using or operating AI and AIoT algorithms is important. Contemporary estimates assume an increase in electricity demand to power AI and AIoT devices by 2050, representing up to 20% of the overall energy demand. In this context, it is important to optimise the benefits and energy costs of large-scale deployment of AI and AIoT-based devices.

AI-driven tools can predict the temperatures of urban structures, aiding in city planning and reducing heat-related risks. Combining AI with other technologies can enhance the effectiveness of climate adaptation infrastructures.

The analysis showed a growing number of publications related to the application of AI to mitigate the phenomenon of urban heat islands. The main contexts for using AI algorithms in architecture are: AI and AIoT applications in urban structures, counteracting climate change, energy and material savings, ecosystem protection, waste management, and ecological transport. According to the authors, future scientific work should focus on developing efficient techniques for integrating various AI algorithms, so they can process vast amounts of data in real time, while simultaneously providing answers to the posed problems.

List of designations

Symbol	Name	Unit
AI	Artificial intelligence	[-]
AIoT	Artificial intelligence of Things	[-]
ANN	Artificial Neural Network	[-]
BN	Bayesian Networks / Batch-Normalization	[-]
NC	Natural Computing	[-]
CV	Computer Vision	[-]
EC	Evolutionary computing	[-]
ML	Machine Learning	[-]
NLP	Natural Language Processing	[-]

FL	Fuzzy Logic	[-]
GANs	Generative Adversarial Networks	[-]
SVM	Support Vector Machine	[-]
DT	Decision Trees	[-]
LR	Linear Regression	[-]
RF	Random Forests	[-]
GA	Genetic Algorithm	[-]
DNNs	Deep Neural Networks	[-]
ICT	Information and Communication Technologies	[-]
PCM	Phase-change materials	[-]
CNNs	Convolutional Neural Networks	[-]
ANFIS	Adaptive Neuro – Fuzzy Inference System	[-]
UHI	Urban heat island	[-]
UAHI	Urban anthropogenic heat index	[-]
LST	Land surface temperature	[-]
IS	Impermeable surfaces	[-]
SUHI	Surface urban heat island	[-]
UCM	Urban Canopy Models	[-]
SVF	Sky View Factor	[-]
PET	Physiologically equivalent temperature	[-]
UTCI	Universal Thermal Climate Index	[-]
WGBT	Wet bulb temperature	[-]

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