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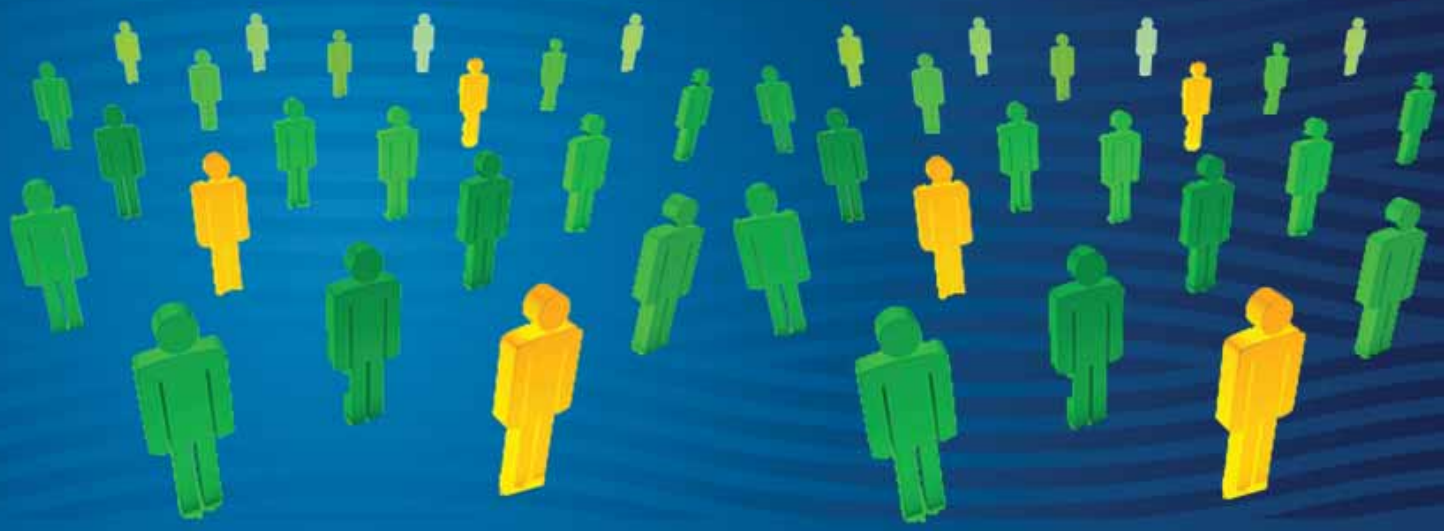

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Tehran Urban Research and Planning Center:
Tehran Municipality,
Tehran, Iran
Email: publisher@ijhcum.net
ijhcum@gmail.com

Editor in Chief
Professor A. Gholipour
University of Tehran,
Tehran, Iran
Email: agholiporut.ac.ir

Managing & Handling Editor
Dr. M. Khodadi
Tehran Municipality
Email: ijhcum@gmail.com

Page Designer
A. Rezaei Soltanabadi
Imajgaran Danesh
ardavanre@gmail.com

Editorial Contact Information
IJHCUM Journal, Khayyam St.,
Building No. 2, Tehran Municipality,
Tehran 1114676111 Iran
Phone: +9821-96015406
Fax: + 9821- 22392096
Emails:
editor@ijhcum.com
ijhcum@gmail .com
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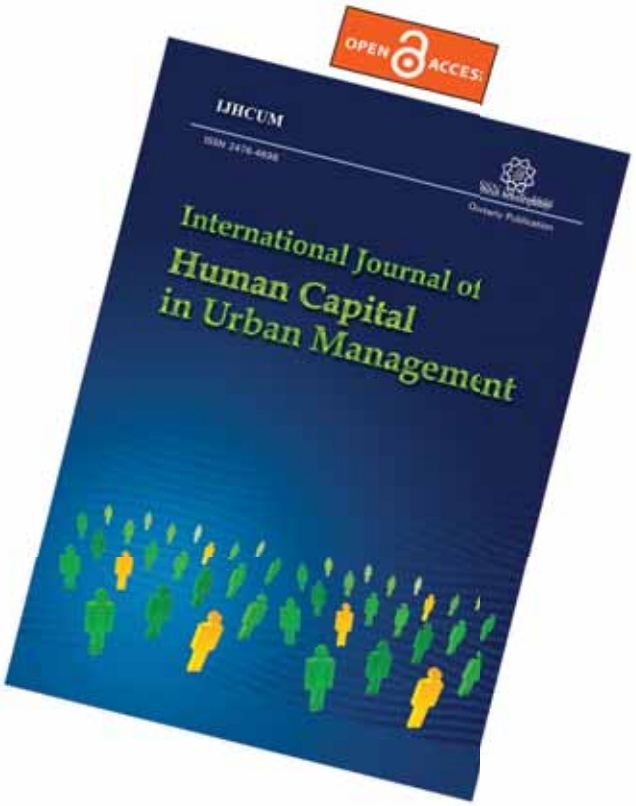

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Fax: +9821- 2224 6104

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ORIGINAL RESEARCH PAPER

The geopolitics of energy cooperation between Turkey and the Balkans

B. Lami

Department of Applied Social Sciences, Faculty of Law, Political Sciences and International Relations, European University of Tirana, Tirana, Albania

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ABSTRACT

BACKGROUND AND OBJECTIVES: Turkey's strategic position as an energy hub between Eastern and Western markets, combined with the Balkan countries' growing need for energy source diversification, necessitated a comprehensive analysis of their energy cooperation. This study aimed to evaluate the geopolitical dynamics of energy partnerships between Turkey and the Balkan region, focusing on infrastructure development and investment patterns from 2013 to 2022. The research objectives were to: 1-analyze the implementation of major cross-border energy projects; 2-assess Turkish investment activity in the Balkan renewable energy sector; 3-evaluate the influence of geopolitical factors on energy cooperation; and 4-identify key challenges and opportunities for future energy partnerships.
METHODS: The study employed a mixed-method approach, combining historical review, geopolitical mapping, and quantitative analysis of energy trade data. Statistical data from international organizations, including the International Energy Agency, World Bank, and Turkish Statistical Institute, were analyzed. A SWOT analysis was conducted to assess strategic cooperation dimensions.
FINDINGS: Turkish investments in the Balkan region during 2013-2022 totalled USD 20 billion, with the energy sector accounting for 35% of foreign direct investment. Major energy infrastructure projects included the Trans-Anatolian Pipeline (1,850 km, capacity 16 bcm/year, USD 11.5 billion investment) and Turkish Stream (1,100 km, 31.5 bcm/year, USD 7.4 billion investment). Turkish corporations invested €5 billion in renewable energy between 2019-2023, with the largest single investment being a 242 MW wind farm in Montenegro (€280 million). The analysis revealed that Bosnia and Herzegovina received the largest share of total Turkish investments (USD 5.5 billion), followed by Serbia (USD 4.5 billion) and North Macedonia (USD 3 billion).
CONCLUSION: The research established foundational theoretical and practical contributions to understanding regional energy cooperation dynamics. The theoretical framework developed through this study advances scholarly comprehension of how geopolitical, economic, and environmental factors interact in shaping energy partnerships. The findings demonstrate that Turkey-Balkans energy cooperation significantly influences regional energy security and economic integration through substantial infrastructure development and renewable energy investments. The research identified critical success factors for future energy partnerships, including geopolitical stability, capital accessibility, and environmental sustainability. These conclusions provide policy implications for regional energy security enhancement and practical guidelines for cross-border energy project implementation. Furthermore, the study established a methodological foundation for analyzing complex regional energy partnerships, contributing to both theoretical discourse and practical applications in international energy cooperation. The findings suggest that successful energy partnerships require integrated approaches to balance traditional energy security concerns with emerging environmental imperatives while maintaining regional stability.

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*Corresponding Author:
Email: *blendi.l@yahoo.com*
Phone: +355695251005
ORCID: 0000-0003-0463-4695

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INTRODUCTION

The geopolitical landscape of energy cooperation between Turkey and the Balkans represents a critical intersection of regional security, economic development, and environmental sustainability. The transformation of global energy markets, coupled with increasing demands for energy diversification and security, has positioned this partnership at the forefront of international energy relations. This strategic relationship gains particular significance as the region navigates complex transitions in energy infrastructure, environmental policies, and geopolitical alignments. Contemporary scholarly discourse has established fundamental aspects of Turkey-Balkans energy relations through multiple theoretical and empirical investigations. Siccardi (2024); Buschle *et al.*, (2020) demonstrate how Turkey's energy diplomacy functions as a cornerstone of its regional influence, while Novikau and Muhasilović (2023) provide quantitative evidence of Turkey's emergence as a regional energy hub through strategic projects such as the Southern Gas Corridor. The geopolitical dimensions receive a comprehensive examination from Badarin and Schumacher (2022), who analyze regional power dynamics, while Tastan (2022) investigates the challenges of aligning Turkey-EU energy cooperation with decarbonization imperatives. The complexity of regional relationships emerges through Guo et al. (2019) analysis of European Union energy policies and Adar (2022) examination of Turkey's strategic positioning. Agoli (2021); Dalay (2022); illuminate Turkey's growing geopolitical influence in the Western Balkans, while Turčalo (2020); Khalilzad et al. (2000) outline Turkey's pivotal role in integrating the Balkans into broader energy networks. The historical and strategic dimensions, initially examined by (Fuller et al., 1993), receive contemporary analysis through (Kirişci, 2016; Akdemir, 2011**;** Agoli, 2021), which traces the evolution of Turkey's regional engagement. (Harxhi, 2017); Özdemir and Serin (2016) provide critical insights into EU-Turkish relations, while Tagliapietra (2015); Papatulica (2015) analyze the strategic significance of energy transit infrastructure. These scholarly contributions establish a theoretical foundation for understanding the multifaceted nature of Turkey-Balkans energy cooperation, though recent geopolitical developments necessitate renewed examination of their conclusions. However, significant theoretical and empirical gaps persist in current understanding. The complex interactions between investment patterns and geopolitical dynamics remain inadequately explained, particularly regarding emerging energy technologies and renewable infrastructure development. The relationship between energy infrastructure development and regional stability requires deeper examination, especially concerning the integration of environmental sustainability objectives with energy security imperatives. Furthermore, existing theoretical frameworks inadequately capture how multiple stakeholder interests converge or conflict in regional energy development, particularly in the context of competing influences from major powers and the European Union's expanding role in regional energy policy. This research addresses these gaps through a comprehensive methodological framework that synthesizes historical analysis, geopolitical mapping, and quantitative assessment of energy trade data. The study evaluates the implementation of major cross-border energy projects, assesses Turkish investment patterns in the Balkan renewable energy sector, and analyses the influence of geopolitical factors on energy cooperation. This approach enables a systematic examination of how political, economic, and environmental factors interact to shape regional energy partnerships while providing empirical evidence for theoretical propositions regarding energy cooperation dynamics. The analysis proceeds through a structured examination of key research dimensions. Following this introduction, the paper presents geographical and historical contexts shaping Turkey-Balkans energy cooperation, analyses major cross-border energy projects, evaluates Turkish investment activities in traditional and renewable energy sectors, and assesses geopolitical influences on cooperation patterns. The study concludes with an evaluation of theoretical implications and practical recommendations for enhancing regional energy cooperation.

MATERIALS AND METHODS

A comprehensive approach was used to study geopolitical and energy relations between Turkey and the Balkans, which allowed a comprehensive assessment of the dynamics and specifics of these relations. At the initial stage of the study, the geopolitical situation in the region was

analyzed using the methods of historical review and geopolitical mapping. This made it possible to identify key milestones and changes in political relations between the countries, as well as to clarify Turkey's geopolitical interests in the Balkans. Next, a case study approach was used to analyze energy strategies and projects involving Turkey and the Balkan countries. This approach allowed for a detailed examination of individual projects, such as gas pipelines, energy bridges, and renewable energy sources, given their importance for energy security and economic development in the region. Quantitative analysis was also used to assess the impact of energy cooperation on economic growth and energy security in the Balkans. For this purpose, the author analyzed statistical data on energy trade, investments in the energy sector, and energy dependence of the countries of the region. Data from international organizations such as the International Energy Agency, the World Bank, and others were used. In addition, to assess the strategic dimension of cooperation between Turkey and the Balkans, a SWOT analysis was conducted, which helped to identify the strengths, weaknesses, opportunities, and threats of this cooperation. This contributed to the formation of reasonable conclusions about the prospects and challenges facing the region in the context of energy security and development.

RESULTS AND DISCUSSION

Geographical, historical, economic, and diplomatic relations form the basis of the ties between Turkey and the countries of the Balkan region. Geographically, these ties are manifested through a 450-kilometer-long common border and through strategic sea lanes, including the Black Sea and the Bosporus and Dardanelles straits, which facilitate interaction between Turkey and the Balkans. The countries of the Balkan Peninsula have access to the Black Sea, the Adriatic Sea, and the Aegean Sea, which underlines their geographical integration with Turkey. From a historical perspective, the common heritage of the Ottoman Empire defines the deep cultural and ethnic ties between the peoples of Turkey and the Balkans. This historical connection has played an important role in shaping contemporary relations between the regions. Economically, Turkey and the Balkan countries are significant trading partners, with Turkey investing in several key sectors in the Balkans, including infrastructure, energy, and tourism. These economic interactions demonstrate mutual benefit and cooperation between the countries. At the level of international relations, Turkey and the Balkan states cooperate through some international organizations, such as the North Atlantic Treaty Organization (NATO), the Organization for Security and Co-operation in Europe (OSCE), and the Black Sea Economic Cooperation (BSEC), which strengthens their political and diplomatic ties. In addition, Turkey's active support for the European integration of the Balkan countries demonstrates a mutual desire to develop stability and prosperity in the region. Thus, the interaction between Turkey and the Balkan region encompasses a wide range of dimensions, including geographical location, shared history, economic interaction, and international ties, which together form a multifaceted and sustainable relationship between these regions. Analysis of Turkey-Balkans energy cooperation from 2013-2022 validates and extends several theoretical propositions established in previous research. The findings align with Siccardi (2024) framework regarding Turkey's strategic positioning as an energy hub while providing additional empirical evidence of investment patterns' impact on regional energy security. The observed investment distribution patterns support Novikau and Muhasilović (2023) assertions about the transformation of regional energy dynamics, though our findings suggest more complex interactions between geopolitical factors and investment decisions. The research extends existing theoretical frameworks by demonstrating how renewable energy integration affects traditional patterns of energy cooperation. While Tastan (2022) identified environmental considerations as crucial factors in regional energy planning, our findings reveal specific mechanisms through which environmental imperatives influence investment decisions and infrastructure development. Furthermore, the analysis advances (Turčalo, 2020) understanding of regional energy security by quantifying the relationship between infrastructure development and energy supply diversification

Energy projects connecting Turkey and the Balkans

Over the past decade, Turkey and the countries of the Balkan region have significantly deepened their energy partnership, which has resulted in the

implementation of some significant projects. These projects, which help to connect the energy systems of both regions, have contributed to increased energy security, diversification of energy sources, and integration of energy markets.

Some of the key energy initiatives that have been implemented are:

1. The Trans-Anatolian Pipeline (TANAP, 2023), launched in 2013, is an important 1,850 km-long gas pipeline connecting the Caspian region to Europe via Turkey and the Balkan countries. Its capacity is 16 bcm of gas per year, and total investments have reached $11.5bn (TANAP, 2023).

1. The Turkish Stream (Gazprom, 2018), implemented in 2015, is a 1,100 km-long gas pipeline designed to transport Russian gas to Turkey and further to South-Eastern Europe. The project has a capacity of 31.5 bcm per year and a cost of $7.4 billion.

1. Launched in 2017, the Interconnector Greece-Bulgaria (ICGB, 2023) connects the gas systems of Greece and Bulgaria through a 182 km pipeline. The capacity is 3 bcm per year and the project cost €240 million.

1. The Trans-Adriatic Pipeline (TAP AG, 2020), commissioned in 2020, runs for 878 km, connecting the Caspian region with Europe via Turkey, Greece, and Italy. Its capacity is 10 billion m3 per year, and the project cost €4.5 billion.

1. The EastMed power grid (East Mediterranean Gas Forum, 2023), a 2023 project, envisages the creation of an undersea cable that will connect the power grids of Israel, Cyprus, Greece, and Italy. The project has a capacity of 2 GW and an estimated cost of €1.7 billion. The impact of these projects has a wide range of positive effects, including increased energy security through diversification of sources and routes of supply, the creation of a more integrated regional energy market in Southeast Europe, and the attraction of investment and economic growth in the region as a whole. It is worth emphasizing that Turkey already plays an important role in the energy security of the Balkans. The implementation of these major energy projects demonstrates both alignment with and divergence from theoretical predictions in contemporary literature. The scale and geographical distribution of infrastructure development validate Siccardi (2024) theoretical framework regarding Turkey's strategic positioning as an energy hub. However, the observed investment patterns reveal more complex interactions between political and economic factors than previously theorized. While Novikau and Muhasilović (2023) emphasized Turkey's aspirations for regional energy leadership, our analysis indicates that project implementation follows more nuanced pathways influenced by multiple stakeholder interests. The Trans-Anatolian Pipeline's development particularly exemplifies Vulović (2023) assertions regarding the importance of multilateral cooperation in regional energy security. However, the project's implementation timeline and investment structure reveal additional complexities in stakeholder relationships not fully captured in existing theoretical frameworks. Similarly, the Turkish Stream project demonstrates how geopolitical considerations influence infrastructure development patterns, extending beyond Tastan's (2022) analysis of environmental and economic factors in regional energy cooperation. The Interconnector Greece-Bulgaria and Trans-Adriatic Pipeline projects provide empirical validation for Turčalo (2020) theoretical propositions regarding regional energy integration. However, our analysis reveals that the interaction between these projects and broader regional energy security objectives manifests more complexly than previously documented. The EastMed power grid initiative particularly demonstrates how emerging technological capabilities and environmental considerations increasingly influence infrastructure development decisions, advancing beyond traditional theoretical frameworks focused primarily on geopolitical and economic factors. This comparative analysis enriches understanding of how multiple factors - including political relations, investment patterns, and environmental considerations - interact to shape energy cooperation outcomes. The findings extend existing theoretical frameworks while providing empirical evidence for the complex relationships between infrastructure development and regional energy security enhancement. Taking into account energy cooperation between Turkey and the Balkans over the past ten years (Fig. 1), according to the analysis of data provided by the Turkish Statistical Institute, British Petroleum (BP) Statistical Review of World Energy, and European Network of Transmission System Operators for Electricity (ENTSO-E), the main trends in the consumption of oil products, natural gas, and electricity production can

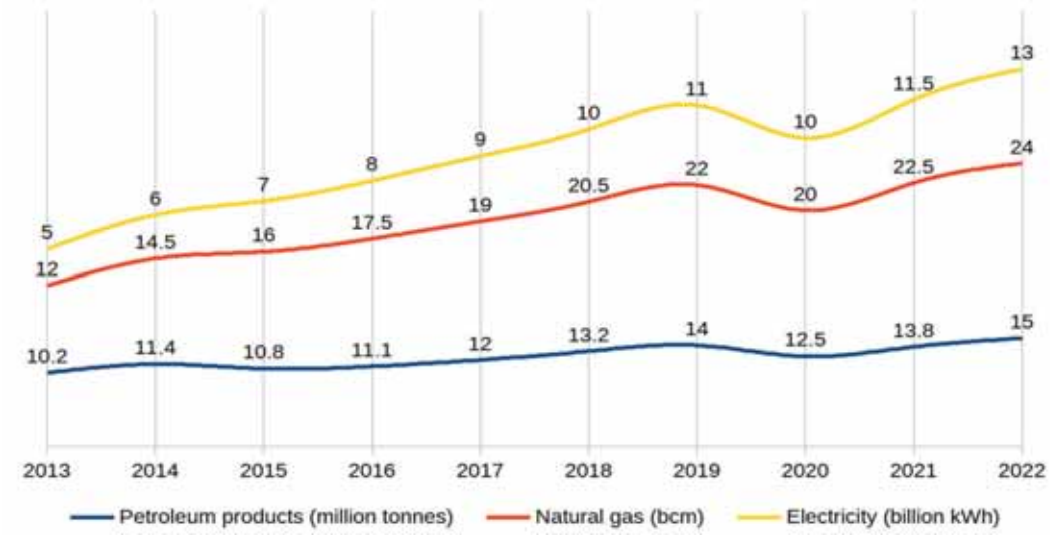

Fig. 1: Turkey's energy transit to the Balkans in 2013-2022

be identified. A general analysis of the data presented in Fig. 1 shows a steady increase in the consumption of oil products, natural gas, and electricity generation, with some fluctuations caused by external factors such as the global pandemic. These trends may indicate a need for further development of energy infrastructure and a transition to more sustainable and environmentally friendly energy sources. Despite the significant achievements in energy cooperation between Turkey and the Balkan region, there are challenges that we believe need to be addressed:

1. *Geopolitical tensions in the region may create obstacles to the implementation and long-term operation of cross-border energy projects.*
1. *Raising the necessary capital to finance major energy initiatives is a complex task that requires investment from a variety of sources.*
1. *The environmental impact is a significant factor in the planning and implementation of energy projects, requiring detailed environmental assessments and measures to minimize negative impacts.*

In the future, energy cooperation between Turkey and the Balkans is expected to continue to strengthen, focusing on: joint solar and wind energy initiatives, which will increase the share of renewable energy sources in the energy mix of both regions; energy efficiency cooperation, which will significantly reduce overall energy demand and improve the economic performance of energy consumption; integration of electricity markets, which will enable the creation of a more open and competitive market. In summary, the energy partnership between Turkey and the Balkans over the past decade has brought significant benefits in the form of increased energy security and regional integration. Overcoming the existing challenges and focusing on common goals in renewable energy, energy efficiency, and market integration can ensure a sustainable energy future for both regions.

Renewable energy development in the Balkans: progress, challenges, and opportunities

Over the past five years, Turkish corporations have made investments worth more than €5 billion in the renewable energy sector in the Balkan region. Thus, the largest recipients of Turkish investments in green energy in the Balkans are Serbia, Montenegro, Macedonia, and Albania (Table 1).

Table 1 shows that Montenegro has the largest capacity of wind power plants, while Macedonia and Albania have the largest capacity of solar power plants. More broadly, these investments reflect the commitment of Turkish companies to support the Balkan region's transition to renewable energy sources, thereby contributing to energy security, environmental sustainability, and economic development in the region.

Table 1. Turkish investments in renewable energy in the Balkans (2019-2023)

Country	Project	Capacity (MW)	Amount of investment, EUR million	Investor
Serbia	Chachak wind farm	158	300	Zorlu Energy
Montenegro	Kochulevo wind farm	242	280	Akfen
Bulgaria	Balchik wind farm	108	150	Enerjisa
Romania	Fetesht wind farm	64	80	Gama Holding
Macedonia	Ohrid solar power plant	50	70	Calik Holding
Albania	Kavaya solar power plant	50	65	Ayden Energy

Turkey's investment activity in the Balkan countries over the past ten years

Over the last decade, the Republic of Turkey has significantly increased its investment activity in the Balkan Peninsula, considering this region strategically important from the historical, cultural, and economic points of view. A study conducted by the Organisation for Economic Co-operation and Development (OECD) shows that between 2013 and 2022, Turkey made investments in the Balkan countries totalling approximately USD 20 billion. The main beneficiaries of these investments were Bosnia and Herzegovina (USD 5.5 billion), Serbia (USD 4.5 billion), and North Macedonia (USD 3 billion). According to the World Bank, Foreign Direct Investment (FDI) from Turkey to the Balkan countries in the period under review totalled around USD 15 billion, in particular in the energy sector (35% of total FDI), the financial sector (20%), transport (15%), and telecommunications (10%). Portfolio investments, according to the International Monetary Fund, amounted to approximately USD 5 billion and included government bonds, equities, and corporate bonds. Turkish investment has boosted economic growth in the Balkan region, where, according to the European Bank for Reconstruction and Development (EBRD), Gross Domestic Product (GDP) is expected to grow by 25% between 2013 and 2022. In addition, Turkish companies have created approximately 100,000 jobs and contributed to infrastructure development, including the construction and modernization of roads, airports, and energy facilities. Turkey's main investments in the Balkan countries are shown in Table 2.

The analysis of Turkish investment patterns in the Balkan region between 2013 and 2022 reveals complex multidimensional dynamics of regional economic integration. Investment distribution demonstrates significant sectoral diversification, encompassing energy infrastructure, construction, electronics, tourism, transport, finance, food industry, metallurgy, automotive, and chemical sectors. The geographical distribution of investments, with primary recipients including Bosnia and Herzegovina, Serbia, North Macedonia, Albania, Montenegro, and Kosovo, indicates strategic patterns of regional economic engagement. The empirical evidence demonstrates several significant trends. First, the energy sector's predominance in investment allocation, accounting for 35% of total FDI, validates theoretical propositions regarding the strategic importance of energy infrastructure in regional development. Second, the substantial investment by ENKA İnşaat ve Sanayi A.Ş. in Serbia's transport sector (€1,100 million) exemplifies the scale of infrastructure development initiatives. Third, the sectoral diversification of investments indicates a comprehensive approach to regional economic integration. This investment pattern analysis provides empirical validation for several theoretical frameworks while revealing new dimensions of regional cooperation. Siccardi's (2024) model of strategic energy diplomacy receives

Table 2: Turkey's investment activity in the Balkans (2013-2022)

Year	Country	Company	Sector	Amount of investment (in millions of euros)
2013	Bosnia and Herzegovina	Enerjis	Energy	230
2013	Serbia	Yenigün	Construction materials	100
2014	North Macedonia	Aselsan	Electronics	20
2014	Albania	Calik Holding	Tourism	50
2015	Montenegro	TAV Airports	Transport	250
2015	Kosovo	Rönesans Holding	Energy	150
2016	Bosnia and Herzegovina	Limak Holding	Energy	200
2017	North Macedonia	Ziraat Bank	Finance	100
2018	Serbia	ENKA	Transport	1100
2019	Albania	Anadolu Efes	Food industry	50
2019	Albania	Limak Holding	Energy	550
2020	Montenegro	Demir Export	Metallurgy	100
2021	Kosovo	Summa	Construction	200
2021	Kosovo	Anadolu Isuzu	Automotive industry	40
2022	Bosnia and Herzegovina	Hayat Kimya	Chemical industry	150
2022	Bosnia and Herzegovina	Summa	Construction	300

substantiation through documented investment patterns, particularly in energy infrastructure development. However, our findings indicate more complex interactions between investment decisions and geopolitical factors than previously theorized. The observed patterns suggest that investment decisions incorporate multiple variables beyond economic considerations, including geopolitical alignment, infrastructure capacity, and environmental imperatives. Projections for future investment trajectories, based on current patterns and economic indicators, suggest the continued evolution of Turkey's regional economic engagement. The European Bank for Reconstruction and Development forecasts indicate potential expansion in several key areas:

1. Renewable energy infrastructure, with projected investments exceeding €8 billion by 2027

2. Infrastructure modernization initiatives, estimated at USD 12-15 billion over five years

3. Digital transformation and smart grid technologies, with projected allocations of €3-4 billion through 2026

However, several external factors may influence these investment trajectories. Global economic conditions, regional political stability, and competition from other international investors, particularly Chinese and European Union entities, present

potential challenges to investment expansion. These dynamics support Vulović (2023); Kasych *et al.*, (2020) observations regarding the complex interplay of international interests in regional development. Furthermore, evolving environmental regulations and sustainability requirements increasingly influence investment decisions, particularly in energy infrastructure projects. This comprehensive analysis demonstrates Turkey's significant role in Balkan regional development while highlighting the complex interactions between economic, political, and environmental factors in shaping investment patterns. The findings suggest the continued evolution of regional economic integration, though success depends on addressing identified challenges in geopolitical stability, competitive dynamics, and environmental sustainability.

The influence of the EU on Turkish-Balkan relations

The relations between the Republic of Turkey and the states of the Balkan Peninsula have traditionally been characterized by complexity and a multi-vector nature. In the context of the post-Yugoslav decomposition of the 1990s, the European Union has emerged as a priority agent in the region, focused on supporting the peace process, stability, and democratic transformation. The process of EU enlargement to the Balkan countries, along with Turkey's active foreign policy in the region, affects bilateral diplomatic ties. Progress in the negotiations on the accession of the Balkan states to the European Union has been slow and complicated, due to the EU's strict criteria in the fight against corruption, organized crime, and ethnic discrimination. Political instability in the Balkan states, as exemplified by North Macedonia, could further complicate the integration process. In addition, Turkey's ambitions for EU membership may become a matter of conflict of interest in the context of European enlargement. The European Union uses economic support, political dialogue, and cooperation programs to strengthen its influence in the Balkan region. At the same time, Turkey actively uses economic investments, cultural ties, and historical heritage to expand its influence. Ankara's goal is to preserve and strengthen its geopolitical status, support the region, and counteract Kurdish separatism. The competition between the EU and Turkey may lead to increased tensions, political polarisation, and complications in the European integration process of the Balkan countries. Thus, the interactions between the European Union and Turkish-Balkan relations are complex and multidimensional. The EU's enlargement to the Balkan region, combined with the competition for influence with Turkey, could lead to increased tensions and complicate the integration process. First and foremost, the EU, Turkey, and other stakeholders must seek to cooperate to ensure peaceful and stable development in the Balkans. The examination of strategic cooperation dimensions through SWOT analysis extends the theoretical understanding of regional energy partnerships in several crucial ways. First, it provides empirical evidence for the theoretical relationship between energy infrastructure development and regional stability. Second, it demonstrates how environmental considerations increasingly influence strategic energy planning, validating and extending Tastan (2022); Tutar *et al.*, (2022) theoretical framework. Third, it reveals specific mechanisms through which geopolitical factors influence energy cooperation outcomes, contributing to a more comprehensive theoretical understanding of regional energy partnerships. The study of the interaction between Turkey and the countries of the Balkan region in the context of strategic geopolitical and energy relations has revealed some significant strengths, weaknesses, opportunities, and threats. To determine strategic priorities, we believe it is advisable to conduct a SWOT-analysis of the strategic dimension of cooperation between Turkey and the Balkans (Fig. 2). As shown in Fig. 2, strengths include the geographical location of both regions, which provides strategic advantages in the development of energy and trade routes, as well as the availability of significant energy resources and economic ties. However, political divisions, dependence on imported energy, and infrastructure constraints are important weaknesses that need to be addressed. Opportunities for the region lie in energy diversification, improved infrastructure connectivity, renewable energy development, and greater economic integration. At the same time, threats include geopolitical instability, external influences on the energy sector, and risks associated with climate change. Given Turkey's geostrategic location as a key bridge between Europe, Asia, and the Middle East, as well as the importance of the Balkans as an important energy and trade corridor, this cooperation has been found to have unique potential for regional stability, security, and development. In recent years, the interaction between Turkey and the Balkan states in the field of energy security and cooperation has become

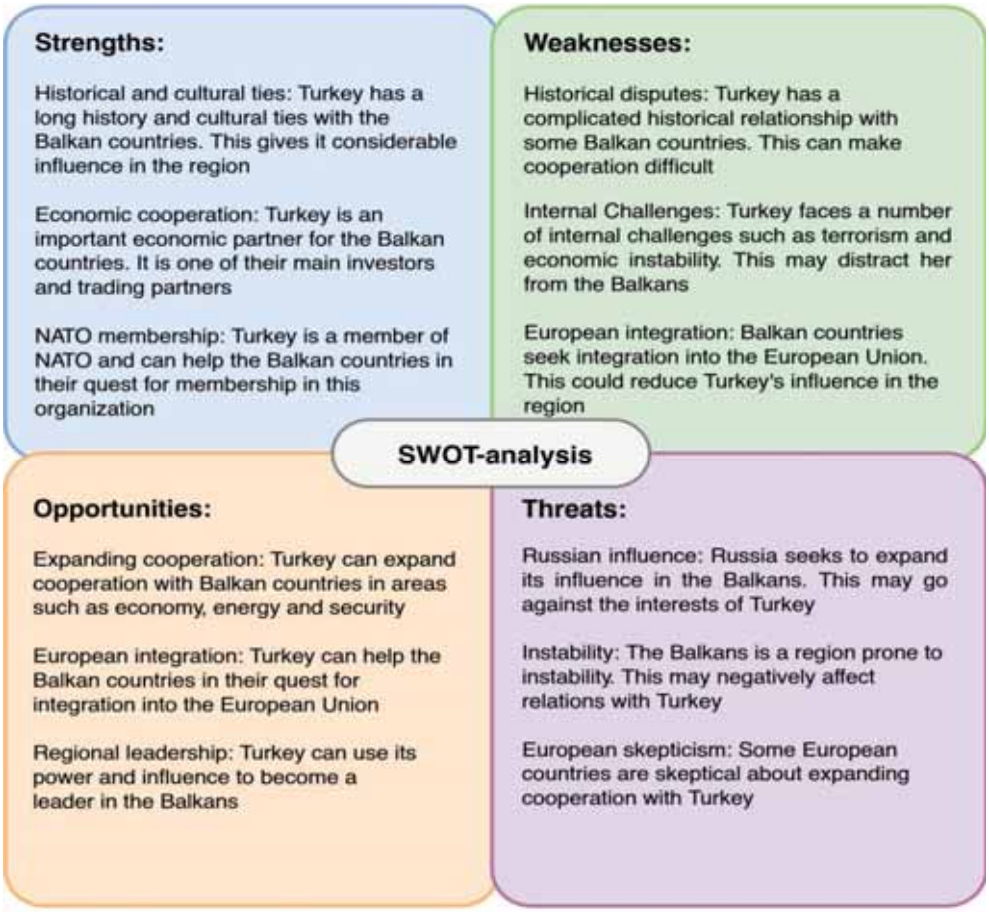

Fig. 2: SWOT analysis of the strategic dimension of cooperation between Turkey and the Balkans

increasingly complex and multidimensional. On the one hand, Turkey seeks to establish itself as an important energy centre that serves as a bridge between Eastern and Western energy markets. On the other hand, the Balkan nations are seeking to diversify their energy resources and reduce their dependence on Russian supplies. Turkey plays a critical role in maintaining energy stability in the Balkans, acting as a transit country for oil, gas, and electricity from countries such as Russia, Azerbaijan, Iran, and others. At the same time, relations between Turkey and the Balkan states are accompanied by certain challenges, including competition for energy resources, geopolitical instability in the Middle East and North Africa, and domestic political risks in the countries themselves. The International Energy Agency warns of possible disruptions in energy supplies due to geopolitical instability, which could lead to higher energy prices. Given Turkey's geostrategic location as a key bridge between Europe, Asia, and the Middle East, as well as the importance of the Balkans as an important energy and trade corridor, this cooperation has been found to have unique potential for regional stability, security, and development. In recent years, the interaction between Turkey and the Balkan states in the field of energy security and cooperation has become increasingly complex and multidimensional. On the one hand, Turkey seeks to establish itself as an important energy centre that serves as a bridge between Eastern and Western energy markets. On the other hand, the Balkan nations are seeking to diversify their energy resources and reduce their dependence on Russian supplies. Turkey plays a critical role in maintaining energy stability in the Balkans, acting as a transit country for oil, gas, and electricity from countries such as Russia, Azerbaijan, Iran, and others. At the same time, relations between Turkey and the Balkan states are accompanied

by certain challenges, including competition for energy resources, geopolitical instability in the Middle East and North Africa, and domestic political risks in the countries themselves. The International Energy Agency warns of possible disruptions in energy supplies due to geopolitical instability, which could lead to higher energy prices. This comprehensive analysis of Turkey-Balkans energy cooperation advances the theoretical understanding of regional energy partnerships while providing practical insights for policy development. The findings demonstrate how multiple factors - including political relations, investment patterns, and environmental considerations - interact to shape energy cooperation outcomes. This research contributes to existing theoretical frameworks by providing empirical evidence of how renewable energy integration affects traditional patterns of energy cooperation while offering practical insights for enhancing regional energy security and economic development.

CONCLUSION

The analysis of Turkey-Balkans energy cooperation advances scholarly understanding of regional energy partnerships while providing substantive implications for theoretical development and practical application in international energy relations. This research advances the theoretical understanding of regional energy cooperation through several significant contributions to the existing body of knowledge. The study develops an integrated analytical framework synthesizing geopolitical, economic, and environmental dimensions of cross-border energy partnerships. This theoretical advancement addresses a critical gap in the literature by elucidating the complex interactions among political relations, investment patterns, and environmental considerations in shaping cooperation outcomes. The research extends existing theoretical paradigms by introducing novel perspectives on renewable energy integration within traditional cooperation frameworks. Furthermore, the study challenges conventional theoretical assumptions regarding the relationship between energy interdependence and regional stability, revealing more nuanced interactions among contributing factors. The research findings yield substantial practical implications for policy formulation and industry practice. From a policy perspective, the evidence supports the development of comprehensive energy cooperation frameworks that incorporate multiple dimensions of regional partnership. Policy considerations encompass energy security enhancement through source diversification, regulatory framework development for investment attraction, and environmental sustainability integration within energy security objectives. The findings advocate for policy approaches that balance traditional energy partnerships with renewable energy development while maintaining regional stability. The implications for industry practice emphasize strategic approaches to investment planning and risk management in cross-border energy projects. The research supports the development of comprehensive risk assessment frameworks that account for geopolitical factors, environmental considerations, and financial variables. These frameworks enable more effective evaluation of investment opportunities and project implementation strategies in complex regional contexts. The study identifies several critical areas for future scholarly investigation. Research priorities include longitudinal analyses of energy partnership impacts on regional development and systematic examination of renewable energy integration effects on cooperation patterns. Additional research opportunities exist in investigating stakeholder dynamics within energy cooperation frameworks and analyzing the environmental implications of infrastructure development. Furthermore, the examination of technological innovation's impacts on partnership evolution presents a promising avenue for future investigation. This research contributes fundamental insights to both theoretical discourse and practical implementation of regional energy cooperation. The findings demonstrate that effective energy partnerships require systematic consideration of multiple variables within complex regional contexts. The theoretical frameworks and analytical approaches developed through this research extend beyond the Turkey-Balkans region, offering broader applications to regional energy cooperation initiatives globally. As international energy systems continue to evolve, these research contributions provide essential foundations for understanding and implementing cross-border energy partnerships. The conclusions establish clear connections between research findings and their implications for theoretical advancement, practical application, and future scholarly investigation, thereby contributing to the comprehensive understanding of regional energy cooperation dynamics. This research thus advances the theoretical foundation and practical

implementation of international energy partnerships while identifying critical directions for future scholarly inquiry.

AUTHOR CONTRIBUTIONS

B. Lami: Conceptualization, Methodology, Visualization, Investigation, Validation, Supervision, Writing - review & editing, Data curation, Software, Validation, Writing – original draft.

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CONFLICT OF INTEREST

The author declares no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the author.

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ABBREVIATIONS (NOMENCLATURE)

bcm	A billion cubic metres
bn	Billion
BP	British Petroleum
BSEC	Black Sea Economic Cooperation
EBRD	European Bank for Reconstruction and Development
ENKA	ENKA İnşaat ve Sanayi A.Ş.
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
km	Kilometre
NATO	North Atlantic Treaty Organization
OECD	Organisation for Economic Co-operation and Development
OSCE	Organization for Security and Co-operation in Europe
SWOT-analysis	(Strengths, Weaknesses, Opportunities, and Threats) analysis
WTP	Willingness to Pay

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ORIGINAL RESEARCH PAPER

Ethnic-sensitive governance: Redefining good governance in an ethnically polarized region

I.K. Gunawan[1,*], M. Taufik[1], N. Imang[2], I.G. Somlai[3]

[1] *Department of Government Science, Faculty of Social and Political Sciences, Mulawarman University, Samarinda, Indonesia*

[2] *Department of Environment Science, Postgraduate Faculty, Mulawarman University, Samarinda, Indonesia*

[3] *Centre for Asia Pacific Initiatives, University of Victoria, Victoria, Canada; and Ethnobureaucratica, Canada*

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ABSTRACT

BACKGROUND AND OBJECTIVES: East Kalimantan has experienced ethnic conflicts and riots in the past. With Indonesia's capital relocating there, concerns about potential ethnic strife are rising. This research seeks to identify a model of good governance suited for ethnically polarized regions to prevent conflicts from escalating. The study focuses on the newly established Nusantara Capital City and its surrounding area. The objectives of this study are threefold: first, to examine whether areas with high ethnic polarization quantitatively show signs of ethnic antagonism or tensions qualitatively; second, to understand the existing mechanisms of ethnic solidarity and mobilization; and third, to identify the key elements that inhibit the transformation of potential conflict into actual conflict from both ethnic and governance perspectives. The significance of this study lies in its efforts to develop an effective model of good governance tailored for regions with high ethnic polarization.
METHODS: Qualitative and analytical-exploratory methods were utilized to analyze both qualitative and quantitative data, with descriptive statistics enhancing the latter's analysis. Nusantara Capital City comprises 54 villages, housing a total population of 201,259, including 1,777 individuals in village bureaucracies. For qualitative data collection, 29 villages were purposively selected based on ethnic polarization, and respondents were chosen through purposive sampling. Additionally, data on the ethnic backgrounds of the 1,777 individuals in the village bureaucracies were gathered from village offices and key informants, resulting in 189 respondents and key informants for this study.
FINDINGS: The results show that all village samples in Nusantara (100%) implement ethnic-sensitive practices in public service delivery. While various ethnic groups are present at management, staff levels, and in community organizations closely connected to village bureaucracies, the village bureaucracy predominantly comprises three major ethnic groups: Javanese, Banjarese, and Buginese, with average representations of 40.01%, 21.23%, and 21.03%, respectively. Among the local minority ethnic groups, Kutai, Paser, and Dayak have average proportions of 4.55%, 3.14%, and 1.84%, respectively. Despite the insufficient focus on the inclusion of vulnerable Indigenous Baliq people in governance, these practices have helped prevent ethnic polarization from escalating into conflict. Improving governance to be more ethnically sensitive could better address the needs of indigenous communities.
CONCLUSION: The findings provide enhanced strategies for policymakers to implement effective governance in ethnically polarized areas or multi-ethnic regions by taking ethnic-sensitive governance into account. This can be accomplished by adopting ethically sensitive governance within government policy.

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71	7	3

*Corresponding Author:
Email: *i.ketut.gunawan@fisip.unmul.ac.id*
Phone: +62 81253743138
ORCID: 0000-0003-3397-4576

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INTRODUCTION

Many countries across the globe are characterized by their multi-ethnic populations, with each ethnic group holding distinct perspectives, values, and interests. This diversity can often lead to tension and conflict. Elites may exploit these differences to advance their agendas, contributing to societal divisions. Consequently, numerous multi-ethnic nations experience recurrent ethnic conflicts, resulting in significant casualties. Indonesia is a diverse nation, comprising 633 ethnic groups and 1,333 tribes and sub-tribes (Ananta *et al.*, 2015). The country has a history marked by violent ethnic conflicts that have claimed thousands of lives. Even in specific regions, such as East Kalimantan Province, which is home to 435 tribes and sub-tribes (Gunawan *et al.*, 2024), instances of ethnic conflict have been reported. The Indonesian government has passed laws (No. 3/2022 and No. 21/2023) to relocate the country's capital from Jakarta to East Kalimantan Province. The new capital city, *Ibu Kota Nusantara* (IKN) (Fig. 1), is being developed in stages, and its main buildings are now ready for use. As a result, the Independence Day celebration on August 17, 2024, was held in IKN, marking the first official celebration outside Jakarta. Concerns have been raised regarding the potential for ethnic conflict in the IKN region, given East Kalimantan's history of ethnic tensions. This issue warrants attention for two key reasons. First, many areas in the newly established capital city are expected to develop into urban environments, necessitating specialized management for ethnically polarized urban areas. Second, there have been instances of ethnic riots in Penajam Paser District, one of the parent districts of IKN, highlighting the need for careful oversight. The risk of ethnic conflict is frequently associated with ethnic polarization. Quantitative research indicates that many villages (*desa/kelurahan*) in IKN display elevated levels of polarization, which suggests a potential for conflict (Gunawan *et al.*, 2024). To gain a more comprehensive understanding of this issue, further qualitative research is necessary to explore regions exhibiting such ethnic polarization. For this reason, the current study employs a qualitative approach. It addresses three key research questions:

1) Do areas characterized by high ethnic polarization quantitatively exhibit significant ethnic antagonism or tension qualitatively?

2) What is the state of ethnic solidarity and mobilization among the primary ethnic groups?

3) What forms of governance can effectively prevent the escalation of potential conflicts (high ethnic polarization) into actual conflicts?

Through a qualitative lens, this study seeks to explore the first question by examining the nuances of ethnic polarization and tension in the selected areas. In the field of conflict studies, Nathan (2005, 2008) critiqued the use of proxy variables and the conclusion of the quantitative analyses conducted

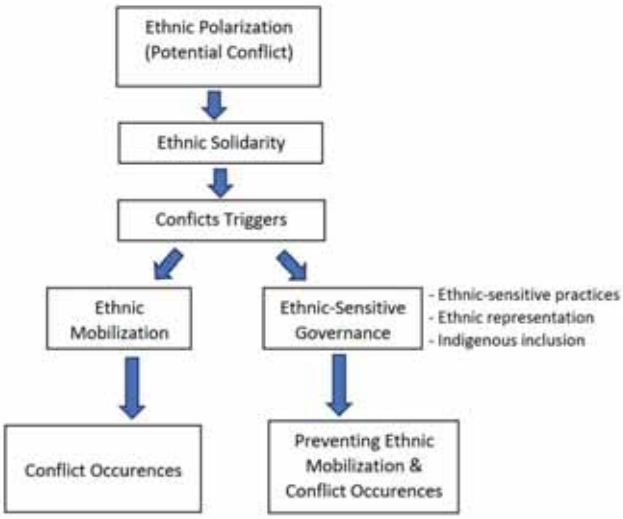

Fig. 1: Model of the theoretical framework

by Collier and Hoeffler, suggesting that they should engage in field observations to gain a more accurate understanding of the complex nature of conflict. This research aligns with Nathan's recommendation. Moreover, this study will explore ethnic solidarity and the mechanisms of ethnic mobilization among dominant ethnic groups and those with a history of conflict in East Kalimantan, to evaluate the potential for polarization to evolve into conflict. The transformation of ethnic conditions into conflict is influenced by the existing institutional framework. In this context, effective governance plays a crucial role in managing multi-ethnic communities to mitigate primordial conflicts. To address the third question, this study will identify the governance structures related to ethnic relations in the region and their impact on either exacerbating conflict or fostering harmony. In discussions of good governance, scholars from various disciplines seek to define relevant concepts within their areas of expertise. For instance, in the context of environmental challenges, there exists a significant discourse surrounding environmentally sensitive governance. This dialogue emphasizes the importance of incorporating environmental sustainability into the broader framework of governance (Triyanti *et al.*, 2023; Purniawati *et al.*, 2020). Furthermore, gender-sensitive governance underscores the necessity of recognizing and incorporating women's voices and participation. It acknowledges their unique interests, needs, and concerns about those of men (Brody, 2009; Naz *et al*., 2023; Manik and Ekayanta, 2024). In the urgent context of climate change, it is evident that there is a rising trend toward climate change-sensitive governance (Meadowcroft, 2009; Ndambwa and Moonga, 2024). This study highlights the importance of ethnically sensitive governance in multi-ethnic countries, where relationships among diverse ethnic groups can vary from harmonious to tense. To mitigate the risk of ethnic conflicts, it is crucial to identify strategies that reduce ethnic tensions and friction, thereby decreasing the likelihood of disputes. This study advocates for the implementation of ethically sensitive governance as an effective approach to addressing this issue. The manuscript will commence by evaluating high ethnic polarization quantitatively through qualitative observation. It will then focus on the conditions of ethnic solidarity and the mechanisms of ethnic mobilization to assess the possibility of transforming ethnic polarization into actual conflict. Finally, the study will discuss the elements of ethnic-sensitive governance in the IKN region, which can either hinder the emergence of ethnic conflict or facilitate the transformation of polarization into conflict occurrences. The objectives of this study are, first, to test whether areas with high ethnic polarization from a quantitative research perspective exhibit ethnic tensions, hostile relationships, or disrespectful relationships among ethnic groups qualitatively. Second, to understand the existing mechanisms of ethnic solidarity and mobilization among ethnic groups, to assess the potential transformation of ethnic polarization into conflict occurrences. Third, to identify the key elements in ethnic-sensitive governance that inhibit the transformation of potential conflict into actual conflict from both ethnic and governance perspectives. To achieve these objectives, the research was conducted in 54 villages in the IKN region in 2024.

Literature review

In the domain of conflict and governance studies, a significant body of literature has emerged from both theoretical frameworks and case-based analyses. It is crucial to examine the progression of these publications to attain a comprehensive understanding of the complex interplay between conflict and governance issues.

Ethnic conflict and ethnic polarization

Conflicts based on primordial issues such as ethnicity and race are prevalent in various parts of the world, not only in newly established democracies but also in well-established ones, whether in so-called developing (e.g., India, Nepal, Myanmar, Sri Lanka, Thailand) or developed nations (e.g., USA, Canada, France, Germany, Spain, UK). To understand these conflicts, experts strive to explain from different perspectives. Works of literature documented four basic perspectives regarding ethnic conflict, namely: primordialism, instrumentalism, constructivism, and institutionalism. Primordialism explains that identity differences stem from blood relations and clans within ethnic communities. These differences can cause competition, hostility, and feelings of superiority. Ethnic identity is viewed as natural or shaped by ancestors and passed down through generations. Ethnic conflicts arise from cultural and traditional

differences, often fueled by shared memories of past atrocities, which makes violence hard to avoid. Constructivism posits that ethnic identity is socially constructed by individuals and groups to differentiate between "us" and "them," often influenced by those in power. Colonial governments have historically contributed to dividing society through subjective classifications, but groups have not always accepted these labels. Ethnic conflict often arises when political regimes collapse, leading to competition among newly defined groups for power, particularly during elections or modernization processes that favor one ethnic group over another. Instrumentalism posits that ethnic conflict arises from external factors rather than the ethnic groups themselves. It suggests that political leaders and conflict entrepreneurs manipulate ethnicity as a tool to mobilize groups against each other for specific goals. To achieve this, they spread injustice and hatred, dragging groups into conflict despite their initially non-political cultures. Institutionalism theory suggests that ethnic conflict arises from factors like political systems and ethnic exclusion. Proponents argue that institutions can both create and resolve ethnic conflict, depending on their effectiveness in managing diversity (Williams, 2015; Yeghiazaryan, 2018; Tepfenhart, 2013; Lieberman and Singh, 2012). The explanations discussed above possess both strengths and weaknesses. While they offer valuable insights into the nature of ethnic conflict, a significant limitation is that these perspectives often rely on broad generalizations. In their attempt to encompass all existing and emerging perspectives, they may overlook the distinctive characteristics of specific conflicts. Despite extensive research on ethnic conflict, scholars continue to debate the effectiveness of existing explanations in providing resolutions to these issues (Kataria, 2018; Coakley, 2017; Weir, 2012). Some researchers have sought to integrate multiple frameworks to capture the complexity of ethnic conflict (Kataria, 2018; Weir, 2012), while others have moved away from traditional models to identify key factors that contribute to such disputes (Gurr, 1973; Choi, 2017; Collier and Hoeffler, 2004). Notably, Gurr (1973) introduced the concept of "relative deprivation," which explains that ethnic conflicts often emerge from the gap between expected and actual outcomes, resulting in feelings of alienation and frustration. Choi (2017) argued that ethnic exclusion is responsible for the emergence of ethnic conflict. Collier and Hoeffler's Greed and Grievance theory is among the most widely discussed conflict perspectives. Through their research, which involved a quantitative analysis of 161 countries, they sought to uncover the motivations behind conflict. Their findings indicate that "greed outperforms grievance" as a driving force in conflict dynamics (Collier and Hoeffler, 1999, 2000, 2004). The terms "greed" and "grievance" have significantly influenced conversations about conflict, with some scholars extending Collier and Hoeffler's explanation to other contexts (Dunne and Tian, 2019; Atanasiu, 2023), while others concentrate exclusively on either greed or grievance (Shaykhutdinov and Bragg, 2011; Denny and Walter, 2014; Chidima, 2017). Nonetheless, Collier and Hoeffler's work has faced criticism for neglecting additional factors, such as ethnic survival. Nathan questioned the reliability of the proxy variables utilized in the study, arguing that they led to unreliable conclusions. He suggested conducting field observations to gain a more accurate understanding of the complexities surrounding conflicts (Nathan, 2005, 2008). Recent research trends in conflict analysis have increasingly focused on examining the ethnic structure of societies to determine the risk of conflict. Ethnic diversity is a key factor in this analysis, which is further divided into three subcategories: heterogeneity, fractionalization, and polarization. As far as ethnic heterogeneity is concerned, some believe that conflict occurs because society consists of various tribes with differences in culture, traditions, and views of life. However, many pluralistic regions and countries can coexist peacefully. Therefore, research has turned to ethnic fractionalization, which is triggered by Easterly and Levine's work on economic inequality related to ethnic division (Easterly and Levine, 1997; Esteban and Ray, 2008). Studies have shown that ethnic fractionalization has a positive impact on economic growth, diversity of livelihood sources, increased income, and tolerance (Ananta *et al.*, 2023; Campos *et al.*, 2009; Gatykaev and Voronetskyy, 2018; Papyrakis and Mo, 2014; Sanjaya, 2022). However, the relationship between ethnic fractionalization and conflict is still uncertain and inconclusive, and it has even failed to be established. Esteban said that "it is fair to say that most of the literature fails to find any significant evidence of ethnic fractionalization as a determinant of conflict" (Esteban and Ray, 2008).

Recent studies suggest that ethnic polarization is more closely related to conflict than fractionalization. To measure ethnic polarization, scholars developed a quantitative index that can be used to calculate the degree of ethnic polarization, along with ethnic fractionalization, within a society (Montalvo and Reynal-Querol, 2002, 2005; Alesina *et al.*, 2003; Esteban and Ray, 2008). It is plausible, therefore, that this study highlights ethnic polarization and tests whether ethnic polarization or communities in an ethnically polarized region show signs of conflict.

Governance and ethically sensitive governance

In the realm of conflict prevention, current literature examines the significance of governance. The term "governance" was first introduced by the World Bank in 1989, defined as the "exercise of political power to manage a nation's affairs" (World Bank, 1989). Following the World Bank's lead, many international organizations have begun to mainstream the issue of governance. The UNDP further elaborates on governance, defining it as "the exercise of economic, political, and administrative authority to manage a country's affairs at all levels," and proposes 19 characteristics of good governance, such as participation, sustainability, transparency, promoting equity and equality, promoting gender balance, tolerating and accepting diverse perspectives, etc. (UNDP, 1997). United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) later defines governance as "the process of decision-making and the process by which decisions are implemented (or not implemented)," and shortens the characteristics of governance into 8 elements, namely: participation, rule of law, transparency, responsiveness, consensus orientation equity and inclusiveness, effectiveness and efficiency, and accountability, and "can be used in several contexts" (UNESCAP, n.d.). Based on this, in discussions surrounding good governance, scholars across various specialized fields strive to define the concepts relevant to their areas of expertise. For example, in the realm of environmental issues, there exists a discourse on environmentally sensitive governance that underscores the necessity of integrating environmental sustainability into the pursuit of good governance. It is vital to ensure that principles such as participation, efficiency, and democracy do not adversely impact the environment (Triyanti *et al.*, 2023; Purniawati *et al.*, 2020). In the pressing context of climate change, one can observe the emergence of climate change-sensitive governance or climate change governance (Meadowcroft, 2009; Ndambwa and Moonga, 2024). The World Bank emphasizes the importance of a government's transparency and accountability in dealing with climate issues and people's participation in policymaking, budgeting, and monitoring for climate action (World Bank, 2022). Additionally, gender-sensitive governance or gender-responsive governance emphasizes the importance of recognizing and including women's voices and participation, acknowledging their distinct interests, needs, and concerns (Brody, 2009; Naz *et al.*, 2023). The topic of gender in governance is of significant importance, particularly when considering the unique challenges faced by women in interactions with governmental and political systems. Women often find themselves in more precarious positions than their male counterparts. This vulnerability is compounded by systemic barriers and cultural dynamics that can further marginalize their voices and diminish their access to resources and opportunities (Manik and Ekayanta, 2024). This is also connected to feminist critiques of the state, which characterize it as "a repressive agent for women." Feminist activists seek to dismantle the patriarchal structure of society by working to eliminate male supremacy within socio-economic and political contexts (Sapkota and Dahal, 2021). For these reasons, integrating gender perspectives into governance is a plausible approach to promoting gender equality and fostering inclusive societies (Singha and Singha, 2024). In addressing the topic of ethnicity, scholars have explored connections between ethnic issues and governance, covering a range of areas including multicultural societies (Koenig, 1998), public goods (Kimenyi, 2006), human rights (Orji, 2001), and ethnic conflicts (Aseka, 1999; Adams, 2009; Chelanga et al., 2009). However, there is currently no established terminology that explicitly links ethnicity and governance, making it difficult to focus on ethnic issues in the context of governance. To address this gap, this study proposes the term "ethnic-sensitive governance," which is specifically intended for conflict prevention purposes. Akinola expresses concerns about threats to governance in multi-ethnic societies, particularly in the form of discrimination based on language, ethnicity, race,

and religion. To address this issue, he recommends fostering a culture of tolerance, encouraging more dialogue, and adhering to the principles of the Constitution (Akinola, 2022). Such discrimination impacts not only politics but all aspects of public life, including public services. Marwan highlights the importance of governance practices aimed at delivering justice for ethnic minorities. He proposed the implementation of equitable justice for ethnic minorities that advocates for the equal treatment of all ethnic groups, irrespective of their ethnic, religious, or cultural backgrounds (Marwan, 2019). In the work of Schlesinger and Devore, the aforementioned refers to ethnically sensitive practices or elements thereof. Schlesinger and Devore highlight the significance of ethnically sensitive practices, particularly regarding the role of government agencies and social workers in ensuring equitable treatment of minority ethnic groups (Schlesinger and Devore, 1995). Haynes and Singh also underscore the necessity for public service professionals, including social workers, to integrate ethnic sensitivity into their practices (Haynes and Singh, 1992). It is essential, therefore, for government entities at all levels to adopt an ethnically sensitive approach in delivering public services, ensuring that all individuals receive equal treatment regardless of their ethnic background. From the perspective of minority groups, this practice can foster greater trust in government institutions and encourage increased participation. This study examines ethnic-sensitive practices through the lens of observable public service delivery to various ethnic groups. In the meantime, Noe et al. noted a significant lack of public understanding and awareness concerning multicultural democracy, which has contributed to ongoing polarization along ethnic, racial, and religious lines within governance. They proposed that governance be managed collaboratively by diverse ethnic and religious communities (Noe *et al.*, 2023). This perspective highlights the importance of ethnic representation in governance within multicultural societies. The broader significance of ethnic representation is further emphasized by Protsyk (2010), Tan and Preece (2021), and Bird (2014), who argue that providing ethnic representation in governments, parliaments, and political parties is essential for allowing various groups to express their voices and interests. In this study, the focus will be on assessing ethnic representation in village governments. Furthermore, Sibble emphasizes the plight of indigenous peoples by highlighting their prevalent poverty and the marginalization of their voices. He argues that political considerations relating to the principle of self-determination often lead governments to systematically deny their indigenous rights and identity and exclude them from national decision-making processes (Sibbel, 2005). A government's economic considerations also play a crucial role, particularly regarding the claim to customary land by indigenous communities (such as those in East Kalimantan), where the land in question can span thousands of hectares, further contributing to their marginalization and limiting their access to natural resources (Gunawan, 2015). To enhance the conditions and status of indigenous peoples, Morris underscores the importance of their representation and participation in governmental systems. He emphasizes the necessity for these communities to express their interests and needs in daily life (Morris, 2021). This perspective is supported by international agencies, which assert that involving indigenous peoples in decision-making processes and committing to a human rights-based approach to governance are crucial for their survival and for alleviating poverty within these communities (Sibbel, 2005). Therefore, acknowledging indigenous rights, facilitating access to natural resources, and promoting their participation in policy-making are key components of indigenous inclusion in governance, reflecting the principles of ethnically sensitive governance. Based on the above discussion, ethnic-sensitive governance addresses three key issues: the adoption of ethnic-sensitive practices, the assurance of ethnic representativeness, and the promotion of indigenous inclusion in governance.

Theoretical framework

Ethnic polarization refers to the concept of ethnic distance and antagonism between ethnic groups, distinct from ethnic heterogeneity and fractionalization. In the theory of ethnic polarization, there is a more direct link between ethnic polarization conflict (compared to ethnic fractionalization and conflict) as ethnic polarization refers to the potential for conflict (Esteban and Ray, 2008; Esteban and Schneider, 2008; Montalvo and Reynal-Querol, 2002, 2005). Experts have developed a method to calculate the level of ethnic polarization in a region

using statistical formulas based on ethnic population data. This calculation results in the Ethnic Polarization Index (EPI) (Ananta *et al.*, 2016; Montalvo and Reynal-Querol, 2002). A higher EPI indicates a greater potential for conflict. However, polarization is only a potential and may or may not transform into conflict. Here, ethnic mobilization by conflict entrepreneurs is crucial, particularly if ethnic solidarity is high. Nevertheless, solidarity mobilization only affects ethnic expression if there are conflict triggers. Many societies try to prevent conflict triggers leading to ethnic mobilization by maintaining respectful and tolerant relations with other ethnic groups. Thus, despite high ethnic polarization, some societies appear harmonious, with inter-ethnic relations seemingly unaffected. This is often due to efforts to prevent conflict triggers from igniting emotions within certain ethnic groups. The government plays a crucial role in preventing the transformation of ethnic polarization into ethnic riots or open conflict. Experts emphasize the importance of designing governance that addresses ethnic issues, especially in multi-ethnic communities (Marwan, 2019; Noe *et al.*, 2023). In other words, the transformation of the ethnic *status quo* into ethnic friction is contingent upon the existing institutional framework. In this context, the role of governance in managing multi-ethnic communities to mitigate earlier or simmering conflicts is paramount. As discussed, governance can be used in several contexts, such as environmental issues, gender issues, and issues of climate change. This study highlights an often-overlooked discourse amidst widespread and high-level primordial conflicts: ethnic-sensitive governance. This concept is particularly vital in multi-ethnic countries. In regions with diverse ethnic groups, relationships may vary from harmonious to consistently tense or adversarial. To prevent ethnic conflicts, it is essential to identify strategies for reducing ethnic tensions and friction, thereby minimizing the potential for conflict. This study advocates for the adoption of ethnic-sensitive governance as a means to tackle this issue effectively. As aforementioned, the concept of ethnic-sensitive governance deals with three key issues: the adoption of ethnic-sensitive practices, ensuring ethnic representativeness, and promoting Indigenous inclusion in governance (Schlesinger and Devore, 1995; Protsyk, 2010; Tan and Preece, 2021; Morris, 2021). Ethnic-sensitive practices involve providing public services without discrimination based on ethnic background (Schlesinger and Devore, 1995). It is common to observe that public services are provided equally to people of different ethnic or racial backgrounds. However, it is common as well that some ethnic groups feel more comfortable and receive more attention when dealing with officials from the same ethnicity. Therefore, it is important to consider ethnic representation in government officials, ensuring that officials come from various ethnic backgrounds rather than just one tribe. In many countries or regions, one will find indigenous people or First Nations. They are mostly backward, undereducated, marginalized, and poor. Therefore, it's crucial to have governance that is sensitive to the needs of indigenous people. This type of governance should be responsive to the rights, access to natural resources, and representation or participation in policy making of indigenous communities (Sibbel, 2005; Saglie, 2020; Feiring, 2013; Barie, 2020; Luturmas *et al.*, 2024). The above explanation is used as a foundation or guidance for this research, which can be simplified into a theoretical framework model as illustrated in Fig. 1.

In the new capital city of Indonesia (IKN), there are 102 ethnic and sub-ethnic groups, which can be grouped into 73 main ethnic groups. Quantitative research reveals that the majority of villages (*Desa/Kelurahan*) in IKN display elevated levels of ethnic polarization, which suggests a potential for conflict (Gunawan *et al.*, 2024). These villages are composed of a population from diverse ethnic groups, from which many work in the government bureaucracy. In addition, in the Sepaku area (Rings 1 and 2 of the IKN areas), there are indigenous people known as the Baliq tribe. The population of this tribe is small, neglected, and therefore might predictably become extinct. As they are situated in the center of the IKN development area, they are the most affected by IKN development. Implementing indigenous inclusion in governance in the development of IKN will make the development more humane and has the potential to contribute significantly to maintaining the image of IKN as a capital built with the principles of ethnically sensitive good governance. A model in Fig. 1 will be used to describe and analyze the situation in the researched areas. This research will provide a clear understanding of governance that is sensitive to ethnic diversity. The results are expected to redefine

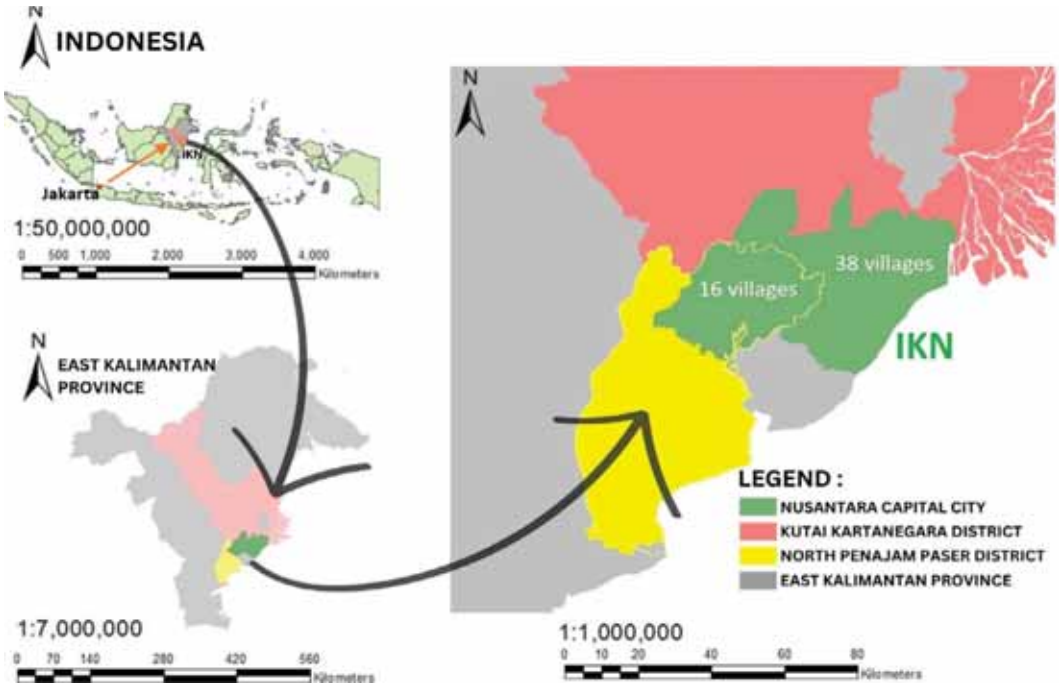

Fig. 2: Research sites

governance by addressing multi-ethnic issues. The inclusion of ethnic issues in managing human capital in the targeted region—urban or suburban areas—is crucial for sustaining economic development as well as for political development, especially in nation-building and social order.

MATERIALS AND METHODS

This research underscores the necessity of ethnically sensitive governance in a polarized region to avert the progression of potential conflict into an actual one. The study was conducted in IKN (Fig. 2), which incorporates areas from the Kutai Kartanegara and North Penajam Paser Districts. IKN, with a total area of 320,429 Ha (252,660 Ha land area and 69,769 Ha coastal area), comprises 54 villages, with Kutai Kartanegara District contributing 38 villages and North Penajam Paser District comprising 16 villages. The research employs qualitative and analytical exploratory methods (Mahdinezhad *et al.*, 2024), utilizing library research or document analysis, along with observation, interviews, and Focus Group Discussions (FGDs).

For the observation, interviews, and FGDs, sample villages were selected using a purposive sampling method based on the known level of ethnic polarization. A total of 22 villages out of 39, representing 56.41%, were selected as sample villages characterized by varying degrees of ethnic polarization, ranging from slightly high to very high levels. In comparison, this research also collected data in areas exhibiting low to moderate levels of ethnic polarization, comprising 7 villages out of 15, or 46.66%. Overall, the research encompasses 29 villages out of a total of 54, yielding a combined representation of 53.79% of the selected sample villages. In these villages, key informants and participants for interviews/FGDs were also chosen through this method (purposive sampling), taking into account their position, expertise, ethnic background, and related experience. Additionally, numerical data on the ethnic representation of 1777 individuals across all 54 villages (management, staff, and community association related to village bureaucracies) were collected from village offices and key informants to enhance the analysis. The total number of respondents and key informants is 189. The main measurement items used in this research are as follows (Table 1).

For quantitative data, descriptive statistics

Table 1: Measurement items

No.	Themes and sub-themes	Questions
1	Evaluating high ethnic polarization quantitatively through qualitative observation	Do areas characterized by high ethnic polarization, from a quantitative research standpoint, demonstrate ethnic tensions, hostile relationships, or disrespectful interactions among ethnic groups on a qualitative level? - Have the respective ethnic groups encountered ethnic conflict, friction, or tension with one another? What are the reasons? - What is the nature of ethnic relations among the various groups in the research area? (e.g. respect, tolerance, etc.)
2	Ethnic solidarity and mobilization	What are the conditions that foster ethnic solidarity and mobilization among various ethnic groups? - Does ethnic solidarity exist among migrant ethnic groups within the research area? If so, to what extent and in what forms is it expressed? - Is ethnic solidarity maintained among local ethnic groups? If so, how significant is it, and in what ways does it manifest? - How does traditional ethnic mobilization occur among these groups? - What does modern ethnic mobilization look like among ethnic populations? - Is the presence of conflict a necessary catalyst for ethnic mobilization?
3	Key elements preventing the transformation of potential conflict into actual conflict	How is the condition of good governance in an ethnically polarized area? What are the key elements that impede the transformation of potential conflict into actual conflict from both an ethnic and governance perspective?
	a. Ethnic-sensitive practices	What is the quality of public service delivery to different ethnic groups? Are there indications of discrimination?
	b. Ethnic representation	What is the ethnic composition of individuals occupying top and middle management positions, as well as the staff and members of community associations associated with village bureaucracies?
	c. Indigenous inclusion in governance	How does the government address the rights of indigenous peoples, particularly in terms of community rights? How do indigenous peoples access natural resources? Are indigenous peoples involved in the policymaking process?

are applied to analyze the collected data. These approaches aim to provide a comprehensive understanding of the observed phenomenon through the analysis of qualitative data, bolstered by solid quantitative evidence (Busetto *et al.*, 2020; King *et al.*, 1995).

RESULTS AND DISCUSSION

Results

Area condition in an ethnically polarized region

The IKN region has a population of 201,259 individuals, encompassing 102 ethnic and sub-ethnic groups, which can be categorized into 73 primary ethnic groups. The ethnic composition of these main ethnic groups is illustrated in Fig. 3.

The predominant ethnic group in the region is the Javanese, comprising 61,616 individuals, which accounts for 30.62% of the total population. The second and third largest ethnic groups are the Buginese and Banjarese, respectively. It is noteworthy that these three groups are migrant communities. In contrast, the local ethnic groups include the Kutai, Dayak, and Paser. An analysis of ethnic polarization across the 54 villages reveals the distribution of these groups, as highlighted in Table 2 under the "Total village" column. The data shows that 39 out of 54 villages in IKN (72%) exhibit elevated levels, ranging from slightly high to very high. The average EPI for these 39 villages is 0.71 (somewhat high) (Gunawan *et al.*, 2024). Nevertheless, among a sample of 29 villages, ethnic tensions have been observed in only 5 villages.

Ethnic tension has been observed in four villages classified with a "somewhat high" level of ethnic polarization, involving native ethnic groups (the Paser and indigenous Baliq) vis-à-vis migrant groups (the Buginese and Javanese) within the core area of IKN development (Rings 1 and 2). The tension with the Buginese is primarily linked to issues of political and economic dominance, whereas the tension with the Javanese stems from land ownership issues associated with the transmigration program and political influence. The ethnic tension with the Buginese is notably stronger than that with the Javanese, attributable to the higher profile of the Buginese compared to the lower profile of the

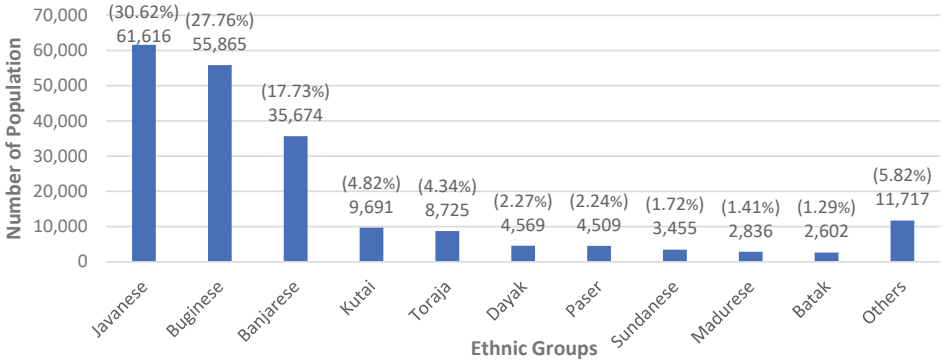

Fig. 3: IKN population by ethnicity (Source: Gunawan *et al.*, 2024)

Table 2: Ethnic Polarization and Ethnic Tension (Sources: Quantitative Field Survey 2023 (Gunawan *et al.*, 2024) & Qualitative Fieldwork 2024 (Interviews, FGDs).)

No	Ethnic Polarization Index (EPI)	Category	Total village	Village samples		
				Total	Total village with normal relations	A total village with ethnic tension
1	0.00 - 0.05	Extremely low	0	0	0	0
2	0.06 - 0.15	Very low	0	0	0	0
3	0.16 - 0.25	Low	2	1	1	0
4	0.26 - 0.35	Somewhat low	0	0	0	0
5	0.36 - 0.45	Slightly low	6	3	3	0
6	0.46 - 0.54	Moderate	7	3	3	0
7	0.55 - 0.64	Slightly high	8	4	3	1
8	0.65 - 0.74	Somewhat high	19	10	6	4
9	0.75 - 0.84	High	9	7	7	0
10	0.85 - 0.94	Very high	3	1	1	0
11	0.95 - 1.00	Extremely high	0	0	0	0
Total			54	29	24	5

Javanese. In Ring 3 of IKN, one village characterized by "slightly high" ethnic polarization between the Banjarese and Toraja groups has also experienced tension, which relates to the establishment of a place of worship. Overall, the ethnic tensions in all five villages are deemed "manageable," as there have been no confrontations or hostile behaviors. Instead, the expressions of discontent manifest as ethnic grievances, while on the surface, there is an apparent coexistence marked by mutual respect. Thus, based on Table 2 and the explanation above, the majority of ethnic groups maintain positive relationships, characterized by mutual respect and appreciation. Although some areas experience ethnic tensions, the overall coexistence is peaceful and largely free from conflict. This situation prompts curiosity about why highly polarized regions do not exhibit signs of ethnic antagonism, instead showcasing mutual respect.

Ethnic solidarity and mobilization

Based on the abovementioned phenomenon, one might argue that the potential for conflict in these highly polarized areas remains inconclusive. Therefore, it is essential to explore the mechanisms of ethnic solidarity and mobilization within these communities. Among the 73 primary ethnic groups in IKN, there are eight major tribes with a history of ethnic conflict or ethnic tension in East Kalimantan. Understanding the dynamics of ethnic solidarity and mobilization within these groups is crucial. Table 3 outlines the key points related to these important issues.

Referring to Table 3, it is evident that ethnic dominance and groups with a history of conflict typically demonstrate high levels of ethnic solidarity. This strong sense of solidarity plays a vital role in facilitating ethnic mobilization. However, not all forms

Table 3: Ethnic solidarity and ethnic mobilization

No.	Ethnic groups	Ethnic solidarity	Ethnic mobilization	
			Traditional	Modern
1	Paser	High, upholding tradition, guardian of the motherland	Ritual and *adat* mechanisms of ethnic mobilization	Digital communication (mobile phones, WA, social media)
2	Kutai	High, common solidarity, guardian of the motherland	No longer using *adat* and ritual-based mobilization, door-to-door (person-to-person)	Digital communication (mobile phones, WA, social media)
3	Dayak	High, upholding tradition, guardian of the motherland	Ritual and *adat* mechanisms of ethnic mobilization	Digital communication (mobile phones, WA, social media)
4	Banjarese	High, common solidarity	No ritual and *adat* mechanisms (person to person)	Digital communication (mobile phones, WA, social media)
5	Javanese	High, common solidarity	No ritual and *adat* mechanisms (person to person)	Digital communication (mobile phones, WA, social media)
6	Buginese	High, common solidarity, self-esteem	No ritual and *adat* mechanisms (person to person)	Digital communication (mobile phones, WA, social media)
7	Toraja	High, common solidarity	No ritual and *adat* mechanisms (person to person)	Digital communication (mobile phones, WA, social media)
8	Madurese	High, common solidarity, self-esteem	No ritual and *adat* mechanisms (person to person)	Digital communication (mobile phones, WA, social media)

of ethnic solidarity result in conflict. Ethnic groups that view themselves as guardians of their homeland and possess traditional mobilization mechanisms are more likely to engage in conflict to defend their land and honor. In contrast, ethnic groups with high solidarity and a robust sense of dignity may also be prone to becoming adversaries in conflict situations. Therefore, while ethnic groups in polarized regions may coexist peacefully, the dynamics of ethnic solidarity and mobilization can create an environment where the potential for conflict exists, particularly if triggering factors emerge and conflict entrepreneurs are present. This raises the question: What underlying factors contribute to the preservation of peaceful relations between ethnic groups in highly polarized regions? The exploration leads to the concept of ethnic-sensitive governance, which effectively manages human capital in these areas.

Ethnic-sensitive governance

Ethnic-sensitive practices

This issue pertains to the provision of public services to the community without discrimination, irrespective of the ethnic backgrounds of its members. Based on interviews conducted in the sampled villages, the findings revealed that in all village samples (100%), there are no disparities in the treatment provided by the village government to residents of different ethnicities. Community members from various backgrounds confirmed this, stating that they receive fair and equal treatment when interacting with the village administration, regardless of their tribal affiliation. These practices are supported by Law 6/2014 on Village (Government), which prohibits village apparatus from "carrying out discriminatory actions against citizens and/or certain community groups" (Article 51) in providing public services. In addition, the law stipulates that any village must "protect and maintain the unity, oneness, and harmony of the Village community in the context of national harmony and the integrity of the Unitary State of the Republic of Indonesia" (Article 67). To support the implementation of this law, the central and district governments allocate substantial budgets to village administrations for their functions. In return, these governments are expected to deliver high-quality public services to all residents, acknowledging their diverse ethnic backgrounds. The village governments are committed to addressing any complaints promptly at the village government office. If a complaint remains unresolved, it will be escalated to higher levels of government, including sub-district, district, and provincial authorities. Citizens who are dissatisfied with public services also have the option to report their concerns to the Ombudsman, either online or offline, as well as through the national complaint-handling website at lapor.go.id. Additionally, the newly elected Vice President has

initiated *Lapor Mas Wapres* (Report to the Vice President) available at https://laporma swapres.id. While some complaints are resolved quickly, others may take longer to address. Ethnic issues tend to receive swift attention due to their potentially harmful repercussions, whereas complaints related to religious matters, such as the construction of places of worship, can be met with mixed responses in certain areas.

Ethnic representation in village governments

Ethnic representation in village governance is essential within multi-ethnic communities, as it fosters an inclusive atmosphere for individuals from diverse ethnic backgrounds who depend on public services. Furthermore, it plays a significant role in mitigating ethnic tensions. The following data provides insight into the ethnic representation within the village government.

Ethnic representation in the top management

The top management structure in this organization is composed of Village Heads and their Secretaries across 54 villages. This leadership group of 101 individuals represents a diverse array of ethnic backgrounds, encompassing 15 distinct ethnic groups. These groups include Javanese, Banjarese, Buginese, Kutai, Paser, Dayak, Madurese, Toraja, Bajau, Mandar, Minangkabau, Makassar, Balinese, Malay, and Sundanese (Fig. 4).

Fig. 4 shows that the top management posts are filled with human capital from many ethnic backgrounds. Among ethnic groups, the top three are Javanese (41.58%), Banjarese (20.79%), and Buginese (18.81%).

Ethnic representation in the middle management

At the middle level, the officials in 54 villages with a total of 271 individuals come from 15 ethnic groups, namely Javanese, Buginese, Toraja, Batak, Paser, Kutai, Madurese, Banjarese, Dayak, Sundanese, Mandar, Butonese, Minahasa, Minangkabau, and Mamasa (Fig. 5).

In the realm of Middle Management within village

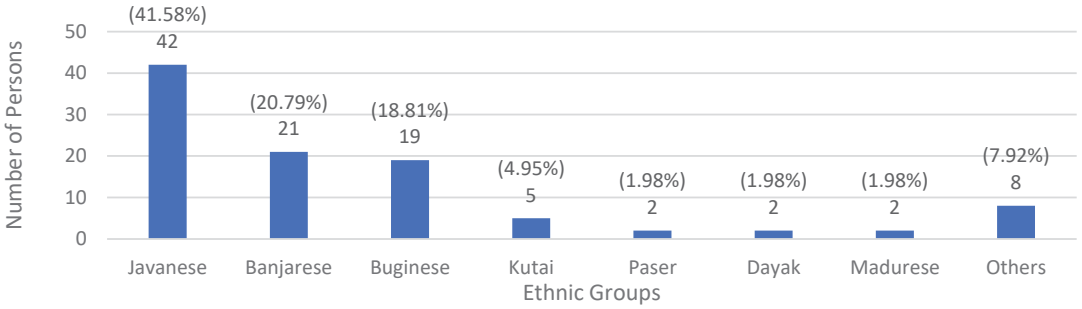

Fig. 4: Ethnic representation across the village bureaucracies in IKN (top management)

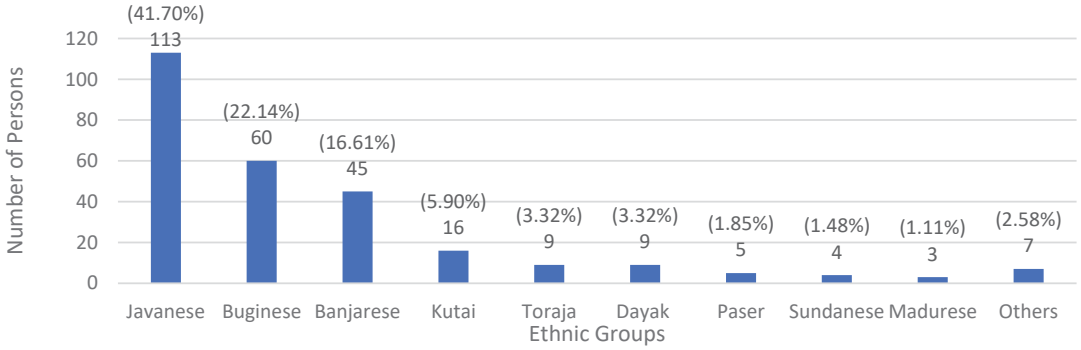

Fig. 5: Ethnic representation across the village bureaucracies in IKN (middle management)

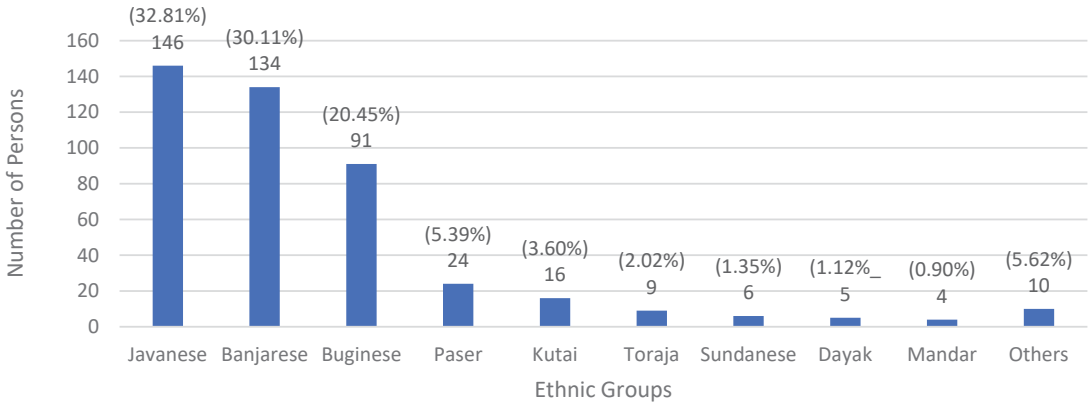

Fig. 6: Ethnic representation across the village bureaucracies in IKN (staff)

bureaucracies, the Javanese community continues to hold a prominent position, showcasing their longstanding influence and leadership. Following them, the Buginese have emerged as the second most represented group, indicating a growing presence in administrative roles. Meanwhile, the Banjarese occupy the third position, reflecting their participation and contributions within the village governance structure.

Ethnic representation at the staff level

At the staff level, 445 employees come from 14 ethnic groups: Javanese, Buginese, Toraja, Batak, Paser, Banjarese, Mandar, Sundanese, Butonese, Minangkabau, Kutai, Sasak, Dayak, and Makassar (Fig. 6).

The Javanese, Banjarese, and Buginese ethnic groups continue to represent the top three demographics at the staff level. In contrast, the local ethnic groups, specifically the Paser, Kutai, and Dayak, occupy the fourth, fifth, and eighth positions, respectively.

Ethnic representation in the community association

A village is composed of numerous Neighborhood Associations, each led by individuals from diverse ethnic backgrounds. Within any village, the Village Consultation Body is also headed by a member of the community. In 54 villages throughout IKN, the total of individuals in both the Neighborhood Associations and the Village Consultation Body is 960 persons, representing 23 different ethnic groups, namely Javanese, Buginese, Toraja, Paser, Banjarese, Bima, Mandar, Butonese, Dayak, Timor, Batak, Sundanese, Sangir, Kutai, Minahasa, Madura, Kaili, Minangkabau, Sasak, Nias, Aceh, Bima, and Bima (Fig. 7).

According to Fig. 7, the Javanese still hold the majority in leadership positions within the Neighborhood Association and the Village Consultative Body, while the Buginese and Banjarese occupy the second and third positions, respectively. Based on the above data, it shows that the village bureaucracy has accommodated ethnic representation. Even if at the Management level the positions only come from one ethnic group, other ethnic groups are accommodated at the staff level or community organizations that are closely related to the village bureaucracy. Although several tribes are accommodated at the management and staff levels, as well as in community organizations closely connected to village bureaucracies, there are three dominant tribes in the village bureaucracies in the IKN, namely the Javanese, Buginese, and Banjarese.

Indigenous inclusion in governance

Indigenous inclusion in governance pertains to a governance approach that is responsive to the needs and concerns of Indigenous peoples, actively addressing the issues they face in their respective regions. This concept is closely linked to three key dimensions: rights (community rights), resources (access to natural resources), and representation (involvement in policy making). In the Sepaku area (Rings 1 and 2 of IKN), the Baliq tribe is an indigenous community with a small population that faces the risk of extinction without proper support and attention. Being situated at the heart of the IKN development,

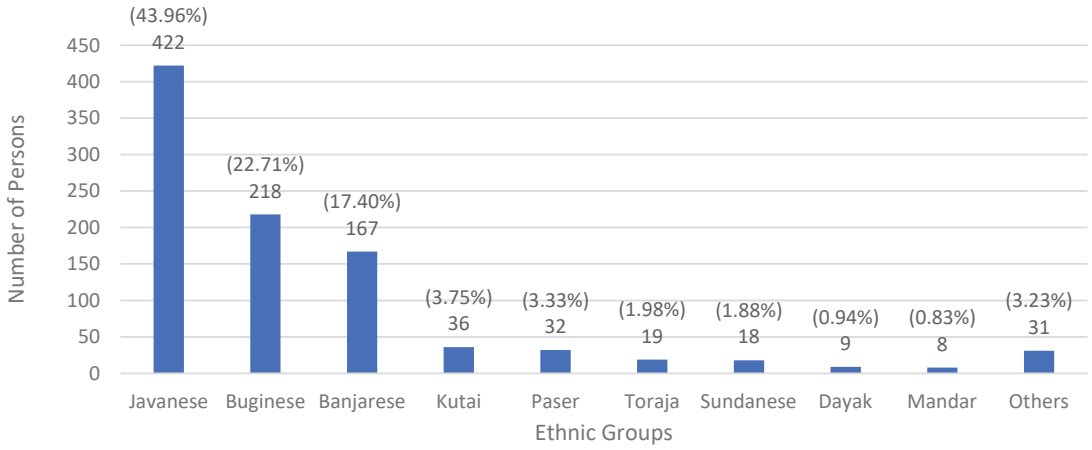

Fig. 7: Ethnic representation in neighborhood association heads and village consultative body

they are significantly impacted by these changes. The implementation of Indigenous inclusion in governance within the context of IKN development can enhance humaneness in the project and contribute positively to the perception of IKN as a capital that embodies the principles of good governance. Concerning the three dimensions mentioned, the rights to their customary territories remain unrecognized, and their access to resources is severely hindered, as all land is increasingly controlled by transmigrants, plantation and forestry concessions, as well as IKN developments.

Discussion

This paper examines the present condition of ethnic polarization, ethnic solidarity, and mobilization, as well as ethnic-sensitive governance in the New Capital City of Indonesia, Nusantara. In terms of ethnic polarization, 39 out of 54 villages in IKN (72%) exhibit elevated levels, ranging from slightly high to very high. The average EPI for these 39 villages is 0.71 (somewhat high). According to conflict theory, increased ethnic polarization suggests a heightened potential for conflict. However, upon qualitative examination, there appears to be a lack of significant tension among ethnic groups. Ethnic relations are generally stable and characterized by mutual respect. Notably, no major friction has been reported between or among ethnic groups, except in the Sepaku sub-district, where tensions exist between the indigenous populations (Paser and Baliq) and transmigrant and migrant tribes (especially Javanese and Buginese). These tensions primarily stem from differences in land ownership and business opportunities. Overall, ethnic relations are predominantly positive, marked by a spirit of mutual respect. In areas characterized by significant ethnic polarization but lacking substantial ethnic friction, it becomes essential to identify mechanisms or institutions for conflict prevention. This necessitates an evaluation of governance issues through an ethnically sensitive lens. Ethnic-sensitive governance encompasses three key aspects: ethnic-sensitive practices, ethnic representation, and the inclusion of indigenous groups in governance. Regarding ethnic-sensitive practices, it is noteworthy that all villages have adopted policies that do not differentiate between ethnic groups when delivering public services. Every individual is served and treated equally. The villages in IKN have made concerted efforts to promote ethnic diversity within their bureaucracies and organizations. This involves ensuring representation from various ethnic groups in management roles and staff, as well as in community-based organizations connected to the village bureaucracy. Such diversity aims to create an environment where residents of different ethnic backgrounds feel comfortable and adequately represented in local governance. Nevertheless, challenges persist concerning the inclusion of the indigenous Baliq ethnic group in governance, particularly related to issues surrounding indigenous land rights, access to forest resources, and participation in decision-making processes. While the current atmosphere seems peaceful and respectful, there exists a latent potential for conflict due to the

quantitative polarization of the ethnic population and the strong traditional solidarity among local tribes, such as the Paser and Dayak. Traditional mobilization mechanisms, grounded in *adat* and ancestral rituals, could be activated in response to conflict triggers. Although no significant conflicts have arisen to date, past incidents in Tarakan (when it was part of East Kalimantan), West Kutai, and Penajam Paser Utara serve as reminders that underlying tensions can escalate when confronted with conflict triggers. The current framework of ethnic-sensitive governance has not yet been fully realized and lacks formal recognition as a definitive policy. Therefore, it is essential to pursue its formal adoption through government policy. This process entails redefining the principles of effective governance and formulating a strategic roadmap to enhance, strengthen, and reinforce this model of governance.

Practical implication

Areas characterized by high ethnic polarization are not necessarily predisposed to conflict. This suggests that residents need not be concerned about the status of their regions, provided they practice tolerance and show respect toward individuals from other ethnic groups. It is imperative to maintain and strengthen the currently favorable ethnic relations in IKN through the establishment of ethnic communication forums, development programs involving diverse ethnic groups, and the organization of cultural festivals. Best practices for delivering equitable public services to diverse ethnic groups should be continued and enhanced. Additionally, the representation of ethnic minorities within the bureaucracy must be improved. Indigenous peoples should be actively involved in the decision-making process, and their rights should be duly acknowledged. Given that the government has not conducted an ethnic-based census after the 2010 census, Nusantara Capital City should endeavor to establish a systematic approach to population management that includes regular updates of ethnic data to support/facilitate ethnic-sensitive governance practices.

Policy implication

The current framework for ethnic-sensitive governance has yet to be fully implemented and does not hold formal recognition as an established policy. It is essential to advocate for its official adoption within government policy. This endeavor involves redefining the principles of effective governance in ethnically polarized regions and developing a strategic roadmap to enhance and bolster this governance model.

Contribution of the study

This study is expected to contribute to redefining the existing governance practice in an ethnically polarized region and adopting and promoting ethnic-sensitive governance within the broader discourses and practices of ethnicity and governance.

Limitations and recommendations of the study

This study has limitations in that it primarily focuses on ethnicity regarding the responsibilities of a caring government, while acknowledging that many other factors can also play a role. Additionally, this study does not connect the ethnic background of officials with their abilities, talents, or performance within a meritocracy framework. In the modern world, staff selection is predominantly based on a meritocracy system rather than the inherent backgrounds of individuals. However, given that ethnic representation could significantly impact conflict prevention, it is advisable to explore the combination of meritocracy and ethnic background to discover a balanced solution. This is particularly relevant as many countries implement quotas for ethnic representation, including the representation of indigenous peoples (Bird, 2014; Tan and Preece, 2021), similar to the quotas assigned for women's representation in governments, parliaments, or political parties.

CONCLUSION

This study has shown that most villages in the IKN region are characterized by significant ethnic polarization in quantitative terms. Qualitatively, however, the current conditions are relatively stable; there are no conflicts or signs of imminent conflict, and residents demonstrate respect and appreciation for one another. A key factor in preventing the potential for conflict from escalating into ethnic mobilization and actual conflict is the practice of ethnic-sensitive governance. Although this approach is not yet fully realized, it has generally contributed to promoting equal treatment, facilitating mutual respect among different ethnic groups, and ensuring equitable recognition for all communities, thereby preventing conflicts. Historically, evidence shows that such apparent stability can be disrupted if governance remains aloof from

sociocultural sensitivities; in other words, simply having apposite rules, regulations, and policies is inadequate without complementary service provision to the public. Therefore, redefining governance in multi-ethnic states or regions is essential as ethnic-sensitive governance. Ethnicity is one of the many community considerations a caring government must heed, alongside housing, utilities, roads, education, health, security, economic development, etc. As such, minority governance issues, while often needing prioritization, also require sufficient human and financial resources to enable the desired (re)orientation and implementation process to overcome critical issues, one that can be complemented by monitoring mechanisms to ensure compliance with commitments. In discussing what the government could do to enhance intercultural harmony, one cannot simultaneously discount the influence of culture itself on the governance process and its related enactment. Therefore, the recognition of issues and the strategies to improve must involve not only the elected officials and staff at a problematic time, but especially if minority groups do not have any or sufficient presence in governance, the identification, selection, and utilization of collaborating representatives from the citizenry at large. These people, with adequate orientation, should contribute to understanding, help reach difficult-to-access community members, and proffer pragmatic, utilitarian advice. Only by incorporating minority group values and perspectives could the local authorities claim that any new regulation or process has common support for a viable outcome. An ideally enhanced governance system proactively seeks and supports improved community involvement through formalized agreements, which facilitates fundamentals such as committing not only to inform minority groups but also to progressively consult with them to seek their perspectives and to iteratively involve, collaborate with, and ultimately empower such citizens with full decision-making responsibility.

AUTHOR CONTRIBUTIONS

I.K. Gunawan was responsible for the research design, data collection, analysis, and the preparation and finalization of the manuscript. M. Taufik assisted with data collection and analysis. N. Imang conducted interviews with indigenous people and performed descriptive statistical analysis. I.G. Somlai offered valuable insights by reviewing, enhancing, and proofreading the manuscript.

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest in publishing this article. The authors also declare that ethical issues like plagiarism, informed consent, misconduct, data fabrication or falsification, double publication/submission, and redundancy have been avoided in the publication process.

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ABBREVIATIONS/GLOSSARY

Adat	Customary law or tradition
Desa	Rural Village (on the same administrative level as *Kelurahan*)
EPI	Ethnic Polarization Index
FGDs	Focus Group Discussions
IKN	*Ibu Kota Nusantara* (Nusantara Capital City)
Kelurahan	Urban Community (on a similar administrative level as *Desa*)
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
WA	WhatsApp

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ORIGINAL RESEARCH PAPER

Organizational structure and creative urban branding: Exploring the mediating role of urban spaces and historical capacities

A. Hamidi[1], A.A Salaripour[1,*], M. Hesam[2]

[1]*Department of Urban Planning, Faculty of Architecture and Art, University of Guilan, Rasht, Iran*

[2]*Department of Geography, Faculty of Literature and Humanities, University of Guilan, Rasht, Iran*

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study explores the role of organizational structure, historical and cultural capacities, and creative urban spaces in enhancing the branding of creative cities. Focusing on Rasht, a historically and culturally rich city in Iran, the research aims to understand the mediating role of creative urban spaces and historical-cultural capacities in the relationship between organizational structure and urban branding. Despite extensive research on urban branding and its determinants, a theoretical gap exists in understanding how organizational structures influence creative city branding through the interplay of historical-cultural capacities and creative urban spaces as mediators. This study seeks to address this gap by providing a comprehensive framework that integrates structural, spatial, and cultural dimensions in urban branding, particularly in creative cities.

METHODS: Using a mixed-methods approach, the study combines a literature review with quantitative data collection. 500 online surveys were distributed among Rasht residents using random sampling. Data were analyzed using descriptive and inferential statistics, including structural equation modeling (SEM-PLS), to test hypotheses regarding the direct and indirect relationships between organizational structure, creative urban spaces, historical-cultural capacities, and city branding.

FINDINGS: The study reveals that the organizational structure significantly influences creative urban spaces (β = 0.654) and historical-cultural capacities (β = 0.713). These mediating factors play a pivotal role in enhancing creative city branding, with historical-cultural capacities demonstrating a stronger impact (β = 0.352) than creative urban spaces (β = 0.212). The model accounts for 54.5% of the variance in creative city branding, emphasizing the critical interplay between organizational structure, cultural capacities, and urban spaces in shaping and strengthening the city's brand identity.

CONCLUSION: This research contributes to the literature on urban branding by integrating organizational structure, cultural capacities, and creative urban spaces as interconnected factors. The findings underscore the importance of cohesive organizational policies, preservation of cultural heritage, and development of vibrant urban spaces in achieving sustainable and effective city branding. Study limitations and suggestions for future research are also discussed.

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*Corresponding Author:
Email: *salaripour@guilan.ac.ir*
Phone: +989128435877
ORCID: 0000-0002-9306-565X

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INTRODUCTION

Cities, as key hubs of development and innovation, have undergone significant transformations in the economic, social, and cultural spheres in the era of globalization. One of the major consequences of these changes is the increasing competition among cities to attract investment, tourists, and intellectuals (Lucarelli & Berg, 2011). In this context, the concept of urban branding has gained growing importance as a strategy to create a distinct and appealing image of cities. Cities that can establish a unique identity through branding are more likely to succeed in this competitive environment (Molaei & Zirak Sima, 2021). In this context, Organizational Structure (OS) and cultural capacities are among the most important factors that can play a key role in shaping the creative identity of a city and enhancing its attractiveness (Hospers, 2003). OS, cultural heritage, and historical capacities significantly boost creativity and promote sustainable urban development. Therefore, the concept of the "creative city" emphasizes the use of local cultural assets and community involvement to strengthen innovation and economic growth (Hamidi *et al*., 2021). Cultural heritage plays a crucial role in urban sustainability by addressing social inequalities and enhancing community resilience, thereby facilitating multifaceted approaches to urban challenges (Naheed & Shooshtarian, 2022). Moreover, integrating culture into urban policies can guide local innovation and inclusive strategies for urban regeneration (Tseva, 2020). The convergence of culture with economic development can stimulate sustainable practices and highlight creativity as a vital social resource (Betlej & Kačerauskas, 2021). Therefore, focusing on culture and history in urban regeneration emphasizes their importance in creating cohesive and sustainable urban environments (Sepe, 2013). In this regard, creating creative urban environments significantly enhances cultural interactions and positively impacts economic growth by strengthening employability in creative industries and attracting investment. Local governments play a key role in this process by utilizing their resources and decision-making capabilities to support cultural and creative industries, which are vital for urban competitiveness and sustainable development (Li & Yan, 2024). The integration of culture and heritage into urban branding significantly enhances urban identity, economic transformation, and sustainable development. Cultural branding strategies, such as associating cities with iconic personalities or events, strengthen the city's unique image, attracting tourists and investors, and thereby stimulating the local economy (Ciuculescu & Luca, 2024). Furthermore, leveraging indigenous settlements through creative tourism not only preserves cultural heritage but also strengthens the city's identity and creates a compelling narrative that engages diverse audiences (Kasemsarn *et al*., 2024). The tangible and intangible elements of a city, including urban design and social activities, play a significant role in shaping its identity, which is essential for effective branding. Moreover, cities that adopt sustainable practices in their branding efforts, such as a commitment to environmental care, are increasingly appealing to modern tourists, thus enhancing their global attractiveness (Morrison & Coca-Stefaniak, 2024). Rasht, as one of Iran's historical and cultural cities, has significant potential to elevate itself to the status of a creative city, thanks to its architectural heritage, cultural events, and unique historical capacities. However, preliminary studies indicate that the current OS of Rasht's municipality and related institutions lacks the necessary capacity to optimally leverage these potentials (Hamidi *et al.*, 2023). An important issue in this context is the lack of coordination and integration in urban policymaking and planning, which has hindered the flourishing of the city's creative brand. Additionally, despite the presence of rich cultural and historical infrastructure, the weakness in urban branding as a strategic tool for attracting investment and tourists has prevented Rasht from fully securing a prominent position in the competition among creative cities worldwide (Hamidi *et al*., 2021). Therefore, this study, focusing on the utilization of Rasht's historical and cultural capacities (HCC) and analyzing the role of OS in creating Creative Urban Spaces (CUS), holds significant importance. In this context, the main research question is: "How do organizational structures, creative urban spaces, and historical and cultural capacities influence the process of creative city branding?" This question paves the way for identifying the interrelations between these factors and gaining a deeper understanding of their role in strengthening the creative city brand.

Literature review

One of the most important elements for branding creative cities is the existence of a strong and cohesive

organizational structure in this field (Moilanen, 2015). Therefore, the organizational structure in the realm of creative city policymaking plays a crucial role in shaping the effectiveness of urban branding initiatives, particularly in leveraging cultural and historical assets and fostering creative spaces. A well-defined organizational framework facilitates better coordination among stakeholders, which is essential for the successful implementation of creative city policies. This is because the enhancement of a city's creative brand is increasingly recognized as a primary goal for urban planners (Rius-Ulldemolins, 2014). In addition, the role of leadership within the organizational structure cannot be overlooked. Effective leadership is vital for creating an environment that encourages collaboration and innovation among stakeholders (Rodrigues & Schmidt, 2021). This underscores the importance of fostering strong leadership that prioritizes the integration of creative sectors within the broader urban development strategy. As a result, the organizational structure in creative city policymaking is fundamental to the successful implementation of urban branding initiatives (Hamidi *et al.*, 2023). Moreover, city branding should be integrated into a broader cultural planning framework that emphasizes the sustainability and governance of cultural assets. This integration allows cities to cultivate a unique identity that resonates with both residents and visitors. On the other hand, the organizational structure must facilitate collaboration among various stakeholders, including government agencies, cultural institutions, and the private sector, to create a cohesive branding strategy that reflects the city's unique identity (Evans, 2014). This integration is essential for fostering a collective identity that is meaningful both to residents and visitors. Furthermore, the development of creative and event-driven urban spaces is significantly influenced by the existing organizational structure. Effective place management combines both tangible and intangible factors to create environments conducive to creativity (Mengi *et al.*, 2017). It is also worth noting that the concept of creative spaces is recognized as a new tool for regional development and a facilitator of urban identity. Creative spaces are now seen as an opportunity to preserve historical centres and architectural landmarks, and consequently, as an opportunity for the cultural development of the city based on the relationship between historical and cultural heritage and modern creative ideas (Comunian *et al.*, 2010). Thus, the approach of creating creative urban spaces requires a collaborative effort between urban planners, cultural stakeholders, and local communities to design spaces that not only attract events but also enhance the overall urban experience (Bertoni *et al.*, 2021). Such insights are vital for creating vibrant urban spaces that foster creativity and innovation (Faludi, 2019). On the other hand, integrating historical and cultural capacities into the development of creative and event-rich urban spaces is essential for effective city branding. This approach not only enhances a city's unique identity but also strengthens economic growth and community engagement. The organizational structure supporting these initiatives plays a central role in ensuring that cultural heritage is effectively utilized to create vibrant urban environments. Historic urban neighbourhoods serve as vital components of the city's cultural identity (Davoodi & Dağlı, 2019). The preservation and enhancement of such neighbourhoods can attract tourism and foster a sense of community pride, which is crucial for sustainable urban development. As a result, the creation of event-rich urban spaces is another vital aspect of utilizing historical and cultural capacities (Lei & Zhou, 2022). Events that honour local culture and history can transform public spaces into vibrant activity hubs, strengthening social interaction and economic vitality (Daldanise, 2020). These initiatives attract tourists and engage local communities, fostering a sense of ownership and belonging. Additionally, the role of creative industries in shaping urban identity cannot be overlooked. Creative spaces play a fundamental role in preserving historic centres while simultaneously strengthening innovation and cultural expression (Skivko, 2022). These spaces serve as platforms for local artists and entrepreneurs, contributing to the city's cultural fabric and attracting visitors. The interaction between historical preservation and contemporary creativity is essential for developing a cohesive urban brand that resonates with diverse audiences (Wu & Chang, 2020). In this context, by strengthening the organizational structure that prioritizes cultural heritage, cities can enhance their unique identity, stimulate economic growth, and promote community engagement (Um *et al.*, 2021). The economic implications of creative city branding go beyond immediate financial benefits.

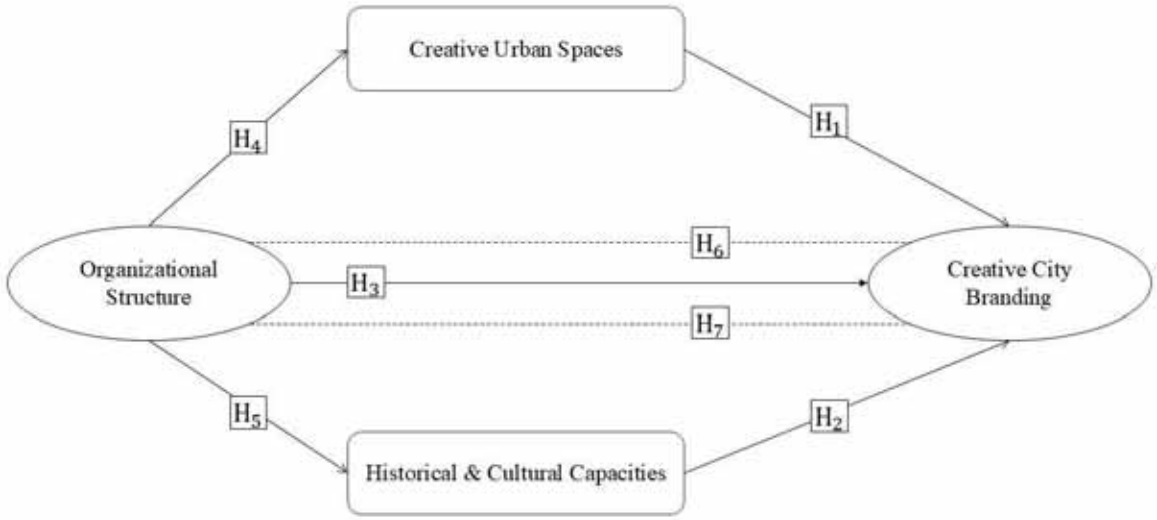

Fig. 1: The theoretical framework

Higher levels of cultural activity are associated with greater regional economic resilience, indicating that investment in creative industries can lead to long-term economic stability. The development of cultural and creative industries not only revitalizes urban areas but also enhances residents' overall quality of life, making cities more attractive to talent and tourists (Miguel & Prieto, 2020). The study aims to examine and analyse the role of the OS indicator in creative urban branding, emphasizing the use of cultural capacities and creating CUS. It seeks to propose practical solutions to strengthen the Creative City Branding (CCB) of Rasht (Fig. 1) and ultimately design an effective model for the optimal utilization of these capacities. Consequently, the findings of this research can be valuable for urban managers and policymakers in enhancing governance quality and urban planning. The insights gained from examining the role of OS and cultural capacities in CCB can serve as a basis for revising managerial strategies and improving urban development policies, aimed at strengthening cultural and social interactions and elevating the status of Rasht both nationally and internationally. The following hypotheses were formulated based on the discussion above:

H1: CUS has a significant and positive effect on CCB.

H2: HCC has a significant and positive effect on CCB.

H3: OS has a significant and positive effect on CCB.

H4: OS has a significant and positive effect on CUS.

H5: OS has a significant and positive effect on HCC.

H6: CUS will mediate the relationship between OS and CCB.

H7: HCC will mediate the relationship between OS and CCB.

MATERIALS AND METHODS

Research methodology

This investigation employs a practical research framework, utilizing a quantitative descriptive approach. The primary objective is to explore how organizational structure influences creative city branding, with mediating factors including the leveraging of historical and cultural assets, the establishment of innovative and event-driven urban environments, and economic revitalization, all evaluated from the perspective of residents. The study focuses on the population of Rasht. Using Cochran's formula (Cochran, 1977), a sample size of 382 participants was calculated. To ensure greater accuracy, 500 online surveys were disseminated among the target group, with respondents selected via a simple random sampling technique.

Data collection methods

Data were acquired through a combination of archival research and empirical methods. The

Table 1: Characteristics of Respondents

Information	Description	Percentage (%)
Gender	Female	60
	Male	40
Age	≤ 35 year	87
	> 35 years	13

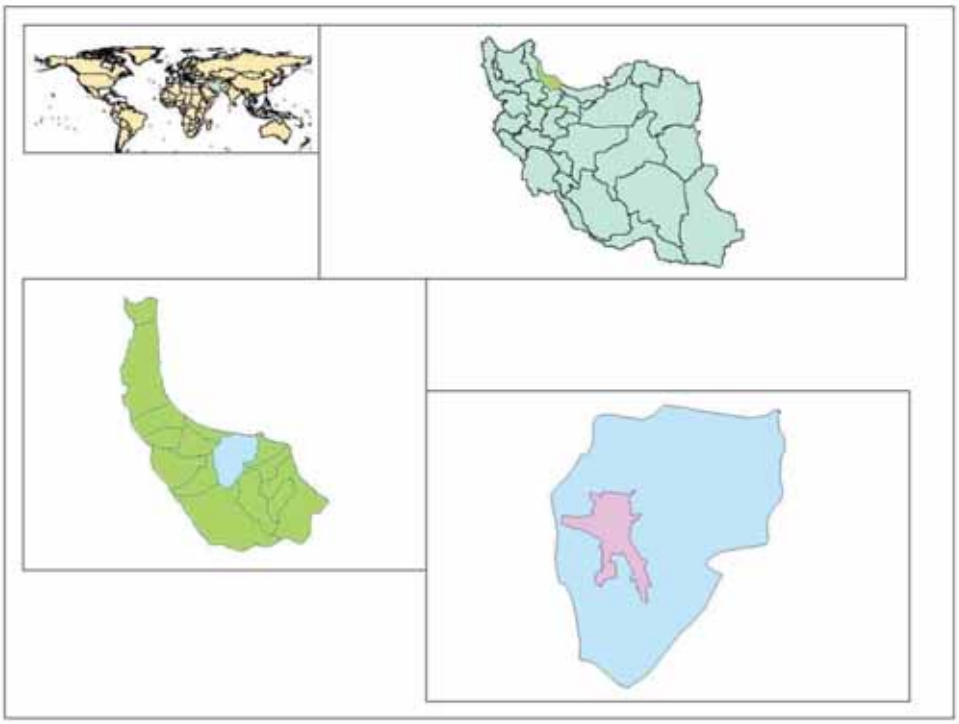

Fig. 2: Geographic location of the study area; (a) Iran, (b) Guilan province, (c) Rasht

archival component involved analyzing reputable academic sources to establish the theoretical and conceptual framework, identifying key dimensions and indicators. The survey instrument was structured as follows: "OS": Assessed using 8 items (Eglins-Eglitis & Lusena-Ezera, 2016; Chatterton, 2000; Hall & Pfeiffer, 2013). "HCC": Measured using 7 items (Markusen, 2006; Bayliss, 2007; Sasaki, 2008). "CCB": Evaluated with 5 items (Dinnie, 2011; Sepe, 2010; Metaxas, 2010). "CUS": Measured using 8 items (Goldberg-Miller, 2019; Shaw, 2014; Mayer, 2013). A five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) was implemented to capture respondents' perspectives accurately. This scale offers a balanced midpoint, allowing participants to express their views comfortably, which enhances response quality (Dawes, 2008). Empirical data were collected by distributing surveys to the target population. The gathered data were processed quantitatively using SPSS software, followed by structural modeling and analysis in SmartPLS3. Demographic and social attributes of the respondents. Detailed demographic and social characteristics, including age, gender, and education level, are summarized in Table 1.

This research focuses on the city of Rasht as its geographical and contextual case study (Fig. 2). The rationale behind choosing Rasht lies in its alignment with the study's thematic priorities, especially considering its official designation as a UNESCO Creative City of Gastronomy and the presence of multifaceted cultural and historical assets. Located along the southern coastline of the Caspian Sea, Rasht stands as the largest and most populous urban center

Table 2: Mean (M) and Standard Deviations (SD) among the research variables

Research variables	M	SD
OS	2.57	0.688
HCC	2.86	0.783
CCB	2.81	0.896
CUS	2.96	0.752

among Iran's northern provinces, celebrated for its rich array of historical and cultural landmarks (Molavi & Hamidi, 2021). Additionally, the city is recognized for its event-driven urban brand, characterized by innovative and creativity-focused urban spaces (Hamidi *et al.*, 2023). Complementing its cultural prominence, the city ranks third nationally for its appeal as a tourist destination (Hamidi *et al.*, 2021). Based on the national census conducted in 2016, the city's resident population was recorded at 956,971 individuals. As the administrative capital of Guilan Province, Rasht accommodates a substantial number of daily visitors, elevating its daytime population to around 1.2 million. Furthermore, this figure may rise to nearly two million during national holidays (Salaripour *et al.*, 2021).

RESULTS AND DISCUSSION

The research findings were analyzed in two sections: descriptive and inferential. In the descriptive findings, the mean values and standard deviations for the variables under study are presented (Table 2). Considering Table 2, it is evident that the CUS index has the highest mean (2.96), while the OS index has the lowest mean (2.57). Moreover, the overall mean of all dimensions is below the average level. On the other hand, in the analysis of standard deviation, the OS index shows the lowest standard deviation (0.688), whereas the CCB index has the highest standard deviation (0.896).

Measurement model

The integrity of the measurement model was examined through five key metrics: factor loadings, Cronbach's alpha, composite reliability, Variance Inflation Factor (VIF), and Rho coefficient, as outlined by Hair *et al.*, (2017) (refer to Table 3). All results in the table indicate strong reliability. Additionally, Additionally, convergent validity was also confirmed (Table 3).

The discriminant validity of the measurement model was examined employing the Fornell-Larcker criterion as proposed by Fornell & Larcker (1981). This approach compares the square root of the Average Variance Extracted (AVE) for each construct against its correlations with other latent constructs. According to Hair Jr *et al.*, (2017), the square root of the AVE for a given construct must exceed its highest correlation with any other construct to establish discriminant validity. The results indicated that the square root of the AVE for each variable surpassed its correlations with other latent variables, thereby confirming the discriminant validity of the model (see Table 4).

Assessment of the Model Validity

The adequacy of the structural model was assessed through the coefficient of determination (R^2) and predictive relevance (Q^2) metrics, as described by Hair *et al.*, (2017) (see Table 5). The R^2 value, reflects the model's explanatory power (Henseler *et al.*, 2015). In this research, R^2 values for all variables exceeded 0.45, indicating a robust fit of the structural model. The predictive relevance was evaluated using the Stone-Geisser criterion (Q^2), with all dimensions yielding positive Q^2 values above 0.20, demonstrating strong predictive capability (Henseler *et al.*, 2014). Thus, the model exhibits significant predictive power. Furthermore, the Standardized Root Mean Square Residual (SRMR) was employed to assess the fit of both measurement and structural models, following Sohaib (2021), An SRMR value below 0.08 is considered acceptable; here, the SRMR was 0.054, indicating a satisfactory fit. Additionally, the Root Mean Square (RMS) Theta was examined, where a value below 0.12 signifies a well-fitting model, and higher values indicate a poor fit (Henseler *et al.*, 2016). The results of these metrics collectively confirm that the proposed model aligns well with the empirical data and demonstrates structural reliability.

Testing the hypotheses

The research hypotheses were evaluated using the Structural Equation Modeling-Partial Least Squares

Table 3: Measurement model

Measure	Factor load	VIF	AVE	CR	A	Rho
OS			0.529	0.899	0.872	0.874
Institutionalization to Promote Indigenous Food Culture	0.711	1.843				
Advisory Committees to Promote the Creative City	0.759	2.123				
Idea Collection and Policy Transformation Process	0.711	1.707				
Defining Operational Goals for Achieving the Creative City	0.774	1.934				
Implementation of Various Projects	0.697	1.618				
Coordination Between Municipality and Cultural Heritage Organization	0.759	1.985				
Coordination Among Urban Organizations	0.777	2.135				
Administrative Structure Efficiency in Utilizing the Creative City Brand	0.618	1.378				
HCC			0.584	0.908	0.881	0.884
Utilization of Cultural Assets	0.784	2.077				
Utilization of Historical Identity	0.796	2.361				
Leveraging the Potential of Historical Monuments	0.759	2.059				
Documentation of Intangible Assets	0.685	1.706				
Attention to Subcultures and Cultural Differences	0.785	2.091				
Transmission of Cultural & Historical Assets to the Younger Generation	0.756	2.015				
Educational and Cultural Infrastructure for Promoting Creativity	0.780	2.105				
CCB			0.677	0.913	0.880	0.881
Success in promoting the brand of this city at the national level	0.784	1.951				
Success in promoting the brand of this city at the international level	0.817	2.168				
Outdoor advertising for brand recognition	0.832	2.261				
Utilizing digital platforms for brand promotion	0.844	2.456				
Creating an appropriate image of the city as a creative city	0.836	2.278				
CUS			0.540	0.903	0.878	0.881
Appropriate platform for event organization	0.638	1.473				
Satisfaction with event organization	0.745	1.788				
Success in enhancing social interactions	0.737	1.808				
Improvement in urban space quality after acquiring the brand	0.801	2.141				
Increased vitality and vibrancy after branding	0.775	2.091				
Strengthening street art and artistic events after branding	0.738	1.854				
Presence of suitable furniture and elements	0.721	1.814				
Utilization of local and cultural symbols	0.713	1.687				

Table 4: Discriminant validity (Fornell-Larcker)

	CCB	CUS	HCC	OS
CCB	0.823			
CUS	0.639	0.735		
HCC	0.692	0.730	0.764	
OS	0.649	0.654	0.713	0.727

(SEM-PLS) approach. The path analysis outcomes confirmed the validity of all proposed hypotheses. Notably, the strongest effect was observed for the relationship between HCC and OS (H5), with a path coefficient of 0.713. This was followed by the effect of CUS on the OS index (H4), with a path coefficient of 0.654. In addition, the mediating hypotheses were examined using the T-test method. The results indicated that both CUS and HCC act as statistically significant mediators in the relationship between OS and Customer Citizenship Behavior (CCB). Overall, the findings affirm that all structural relationships—both direct and mediated—are positive and statistically significant. A summary of the path coefficients, t-values, p-values, and significance levels is presented in Table 6.

The results of the path analysis indicate significant and positive relationships between the various variables in the theoretical model of the research. Based on the findings of this analysis, the first

Table 5: Structural model.

Construct	R^2	Q^2 (=1-SSE/SSO)	SRMR	RMS Theta
CCB	0.545	0.345		
CUS	0.426	0.212	0.053	0.116
HCC	0.507	0.276		

Table 6: Results of direct and mediating hypotheses testing

Hypothesis	Constructs	Path Coefficient	T statistics	P values	Result
H1	CUS -> CCB	0.212	3.643	0.001	confirmed
H2	HCC -> CCB	0.352	6.138	0.001	confirmed
H3	OS -> CCB	0.259	5.222	0.001	confirmed
H4	OS -> CUS	0.654	23.916	0.001	confirmed
H5	OS -> HCC	0.713	30.32	0.001	confirmed
H6	OS -> CUS -> CCB	0.139	3.581	0.001	confirmed
H7	OS -> HCC -> CCB	0.251	5.948	0.001	confirmed

hypothesis was confirmed, which shows that the CUS index has a positive and significant impact on CCB (β = 0.212, t = 3.643, p = 0.001). The second hypothesis was also confirmed, indicating that the HCC index has a positive and significant impact on CCB (β = 0.352, t = 6.138, p = 0.001). The third hypothesis was also supported, showing the positive impact of the OS index on CCB (β = 0.259, t = 5.222, p = 0.001). Additionally, the findings from the path analysis revealed that the fourth hypothesis was confirmed, indicating that the OS index has a positive and significant impact on CUS (β = 0.654, t = 23.916, p = 0.001). The fifth hypothesis was also confirmed, showing that the OS index has a positive impact on HCC (β = 0.713, t = 30.32, p = 0.001). In addition to the direct paths, the mediating effects were assessed using the T-test, and both indirect hypotheses were statistically supported. The sixth hypothesis (H6) demonstrated a significant mediating effect of CUS in the relationship between OS and CCB (β = 0.139, t = 3.581, p = 0.001), while the seventh hypothesis (H7) revealed a mediating effect of HCC in the same relationship (β = 0.251, t = 5.948, p = 0.001). Overall, the empirical findings validate the structural relationships within the proposed model, confirming that both direct and mediated pathways significantly contribute to the prediction of Customer Citizenship Behavior. These relationships are also visually illustrated in Fig. 3.

H1: CUS has a significant and positive impact on CCB.

The findings indicate that the creation of creative urban spaces provides a suitable platform for promoting and strengthening the creative city brand. Creative urban spaces, through the organization of various cultural, social, and economic activities, can link the visual image of a place to its brand identity. The presence of valuable historical and cultural elements in these spaces allows the brands to compete globally. This result is consistent with previous studies that emphasized the importance of urban spaces in creating city identity and enhancing brand recognition (Rezvanpour & Bayat, 2017). Creative urban spaces can play a significant role in fostering social interactions, enhancing environmental aesthetics, and providing a platform for cultural events. These features not only improve the living experience of citizens but also present a more positive image of the city as a creative hub. Specifically, studies have shown that the presence of appropriate furniture, local and cultural signage, and high-quality public spaces can have a significant impact on attracting public attention and strengthening the city's brand (Brown *et al.*, 2003).

H2: HCC has a significant and positive impact on CCB

The findings indicate that utilizing the historical and cultural capacities of a city can play a significant role in strengthening its creative city brand. This is because cultural and historical neighborhoods and buildings can create new creative areas and transform city brands (Evans, 2014). This result aligns with previous studies that emphasize the importance of focusing on cultural heritage and identity in promoting city branding (Stedman, 2003; Evans,

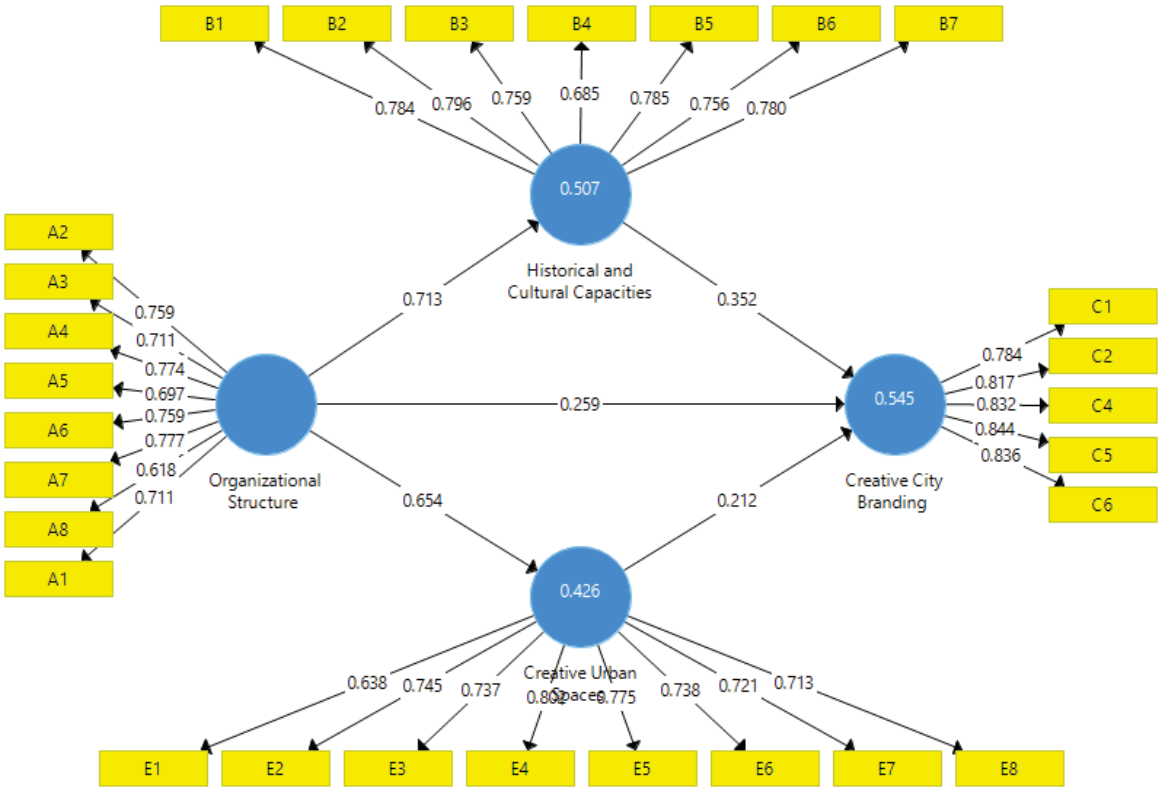

Fig. 3: Measurement model

2014). Historical and cultural capacities, including historical monuments, cultural infrastructure, and the transmission of cultural values to new generations, can contribute to enhancing the credibility and attractiveness of the city brand. Specifically, these capacities not only strengthen the sense of belonging and social identity but also help the city to be recognized as a unique place with a rich cultural heritage. The results of these studies show that these factors can reinforce the sense of respect and value towards the city in the minds of the audience and tourists (Lewicka, 2011).

H3: OS has a significant and positive impact on CCB

The findings highlight the key role of organizational structures in facilitating urban branding processes. Efficient organizational structures can contribute to strengthening the city's brand image by improving coordination between urban institutions, managing resources effectively, and developing aligned policies. Previous research has emphasized that cities with transparent and flexible organizational structures are better positioned to enhance their city brand. For example, creating coordination between public and private sectors, implementing cultural projects, and utilizing institutional infrastructure play a significant role in improving urban branding indicators (Ciuculescu & Luca, 2024). On the other hand, studies have shown that there is a meaningful relationship between organizational structure and creativity. When an organization is flexible and moves toward an organic structure, it fosters creativity. In organizations that have moved away from traditional structures and adopted modern organizational frameworks, creativity has flourished (Shoghi *et al.*, 2013). As a result, this not only helps attract both foreign and domestic investments but also increases citizen participation in urban development processes. Moreover, the results suggest that strong organizational structures can help create cohesive strategic visions for the city brand. In this context, the analysis identifies three key components of the organizational structure index that have the greatest impact on creative city branding: coordination between the municipality

and the cultural heritage organization, coordination among urban organizations, and the definition of operational goals to achieve a creative city. These components play a crucial role in fostering managerial cohesion, optimizing the use of historical and cultural assets, and implementing integrated urban branding policies. Thus, practically speaking, establishing coordinating institutions between public and private sectors, formulating integrated strategies for cultural asset utilization, and defining targeted operational programs for urban development can significantly enhance the city's creative identity and elevate its competitiveness at both national and international levels.

H4: OS has a significant and positive impact on CUS.

The findings emphasize the importance of organizational structures in the development and enhancement of creative urban spaces. Strong and flexible organizational structures can foster the creation of adaptable and creative social spaces by facilitating management and coordination among various urban institutions. These spaces not only provide venues for social and cultural interactions but also improve the quality of life for citizens (Sanei *et al.*, 2018). Specifically, studies have shown that the flexible design of public urban spaces and coordination in organizational planning can influence the expansion of social connections and strengthen a sense of community cohesion. These spaces, by creating multifunctional and adaptable environments, provide conditions in which citizens can engage in a variety of social activities and develop a greater sense of attachment to their surroundings (Gehl, 2011). Moreover, the results of the current study indicate that innovative approaches to managing organizational structures can have a direct impact on the quality of urban spaces and the level of citizen participation.

H5: OS has a significant and positive impact on HCC.

The findings suggest that organizational structure and, consequently, policymaking in creative cities can significantly enhance the city's capacities and attractiveness by strengthening cultural assets and historical identity. An effective organizational structure in local policymaking, focused on preserving and enhancing cultural heritage as a driving force in creative cities, is essential. This is because historical cities with cultural and artistic potentials if supported by a cohesive organizational structure and the selection of appropriate strategies, can leverage these sustainable resources to improve their branding. In this regard, previous studies have also shown that efficient organizational structures and coordination among urban institutions can contribute to the development of creative spaces and the strengthening of cultural capacities. For instance, recent research on the importance of organizational structures in the development of public spaces indicates that coordination among urban institutions and their support for cultural projects plays a key role in improving the quality of urban spaces and increasing social participation (Musterd & Gritsai, 2013; Iranmanesh *et al.*, 2021; Kakiuchi, 2016; Kourtit & Nijkamp, 2019). These findings suggest that organizing urban institutions in a way that can effectively support cultural capacities can help strengthen the city's brand and increase its cultural appeal. This can be achieved through effective coordination and proper management of resources and policies within urban institutions, thereby contributing to the realization of urban development goals.

H6: CUS will mediate the relationship between OS and CCB.

H7: HCC will mediate the relationship between OS and CCB.

The findings indicate that appropriate organizational structures can influence the strengthening of city branding through various pathways. The first pathway, from OS to CUS and then to CCB, suggests that urban organizations can directly and indirectly impact branding. The second pathway, from OS to HCC, and then to CCB, shows that investment in cultural and historical infrastructure can also contribute to strengthening the city's brand. Ultimately, examining these two pathways reveals that organizational structure, as a key factor, can support city branding by fostering creative urban spaces and historical and cultural capacities. Although both pathways have a positive impact, the pathway from organizational structure to historical and cultural capacities typically has a stronger effect on city branding. This is because enhancing historical and cultural capacities plays a fundamental role in creating a stronger and more

distinctive urban identity. To achieve this outcome, urban planners should adopt strategies that focus on developing cohesive organizational structures and supporting urban capacities, thereby effectively contributing to the enhancement of city branding.

Suggestions

It is recommended that urban management focus on the development of creative public spaces. These spaces can strengthen the urban identity of Rasht by emphasizing its cultural and historical symbols and improve the citizens' quality of life. Urban management can implement policies that emphasize strengthening street art, organizing creative events, and using cultural symbols. These strategies can help create more creative urban spaces while enhancing the quality of life in Rasht. To achieve this, it is essential that urban planning be based on coordination among various urban institutions to ensure the effective implementation of these projects. Additionally, urban management in Rasht should focus on strengthening its cultural and historical infrastructure. This includes investing in the preservation and development of historical sites, restoring cultural buildings, and integrating cultural and historical elements in the design of public spaces. By incorporating culture into urban planning and creating cultural spaces such as museums and galleries, social interactions can be enhanced, and the living experience of citizens can be improved. Active citizen participation in urban management processes and the development of these spaces also lead to the strengthening of the urban brand. The use of modern technologies such as virtual reality and augmented reality to create engaging experiences and digital landmarks can also contribute to strengthening the urban brand. To support this approach, Rasht's urban management should review and strengthen its organizational structures. This includes improving coordination among urban institutions, defining clear strategic goals, and implementing supportive policies for creative projects. Efficient organizational structures can help improve the quality of public spaces and increase social interactions. Previous studies have shown that coordination among urban institutions and structural support can enhance the quality of urban spaces and strengthen the urban brand. Therefore, Rasht's urban management should focus on strengthening these aspects to contribute to sustainable urban development and improve the quality of life for citizens. Finally, it is recommended that Rasht's urban management review and strengthen its organizational structures to better support cultural and historical capacities. This involves improving coordination among urban institutions, developing supportive policies, and allocating resources to cultural projects. By implementing these changes, a stronger urban identity and more effective branding can be achieved. Future studies can focus on examining the more precise impacts of these relationships on other aspects of urban branding to provide more practical solutions for improving urban management and sustainable development in Rasht.

Limitations of the study

The limitations of this study include sampling from a single city, Rasht, which may limit the generalizability of the findings to other cities and regions. The focus of this study is on a quantitative analysis of OS and urban branding, which may not fully address the complexities and cultural and social differences that influence this relationship. Additionally, the study did not thoroughly examine intervening variables and specific cultural factors. These variables, such as cultural values, social norms, and historical influences, may affect how organizational structures influence urban branding.

Suggestions for future research

For future research, it is recommended to conduct further studies comparing different cities and regions to better understand the cultural, social, and economic differences that influence urban branding. Research focusing on the impact of various creative public spaces and cultural heritage can contribute to a more precise analysis of how these spaces affect social interactions and urban branding. Utilizing qualitative methods, such as in-depth interviews and case studies, can provide a better understanding of how creative spaces and cultural heritage interact with urban structures and their impact on urban branding. Additionally, studies on the structural impacts on creative urban environments in different cities, along with comparisons of OS, can help identify key factors affecting urban branding and suggest more effective strategies for improving urban management and strengthening city branding in the future. These approaches can lead to sustainable

urban development and the enhancement of urban identity across different regions.

CONCLUSION

This research investigates the role of organizational structure, creative urban spaces, and historical capacities in creative urban branding, offering significant theoretical, practical, and managerial implications. From a theoretical perspective, the findings demonstrate that organizational structure has a meaningful impact on creative urban spaces and historical and cultural capacities, which, in turn, act as mediating variables in strengthening creative urban branding. These results not only contribute to the development of the theoretical literature on urban branding but also emphasize the importance of integrating organizational indicators, urban creativity, and cultural heritage into theoretical models of branding. Furthermore, this study presents a new approach to examining the mutual impacts of structural and cultural factors on urban branding, which could serve as a basis for future research. From a practical perspective, the results indicate that creative urban spaces and historical and cultural capacities directly contribute to strengthening creative urban branding. The findings of this research provide valuable tools for urban managers and policymakers to develop creative and effective strategies for urban branding. In particular, preserving and enhancing HCC alongside the development of creative urban spaces can create a distinctive identity for cities and improve their competitive position both nationally and internationally. From a managerial perspective, the study emphasizes the importance of creating an efficient OS that aligns with urban development goals, especially in the realm of creative urban branding. Urban planning should adopt a creative approach based on preserving cultural heritage, which will strengthen interactions among relevant institutions and improve the performance of OS. Additionally, leveraging innovative policies can foster the enhancement of CUS and cultural and historical capacities, ultimately contributing to the strengthening of urban branding. Overall, this research highlights the significance of integrating OS, CUS, and cultural and historical capacities in the process of creative urban branding. The results of this study can serve as a roadmap for urban managers and policymakers, helping them achieve sustainable urban development and a lasting urban brand. One of the key opportunities for cities lacking tangible heritage is the development of man-made and intangible attractions within the framework of creative city strategies. These elements, which are not constrained by time or tradition, can significantly contribute to urban branding by fostering unique cultural experiences. In this context, creative urban spaces—such as local festivals, cultural markets, and artistic events—enhance the city's identity and social engagement, aligning closely with branding goals. However, such initiatives must balance investment-driven objectives with citizens' quality of life and cultural diversity. The success of these strategies depends on effective organizational structures capable of promoting inclusive, participatory policymaking and coordinating between institutions. When properly managed, temporary and adaptive spaces can reinforce cultural identity, stimulate local economies, and generate memorable urban experiences, as demonstrated in Rasht's gastronomic branding initiatives. In conclusion, Rasht's urban branding potential lies in its integration of cultural heritage, food identity, and creative entrepreneurship, supported by distinctive natural and spatial characteristics. These elements, when aligned with cohesive organizational structures and strategic urban planning, contribute to a dynamic and context-sensitive branding model. While the findings offer valuable insights, their application should be approached with caution due to the unique social and cultural fabric of the city.

AUTHOR CONTRIBUTIONS

A. Hamidi contributed to data analysis, interpretation, and data collection. A.A. Salaripour was responsible for conceptualization and overall supervision of the research process. M. Hesam contributed to methodology development, theoretical consultation, literature review, and manuscript preparation. All authors reviewed and approved the final version of the manuscript.

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ensure its scientific rigor and contextual relevance.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

AVE	Average Variance Extracted
CCB	Creative City Branding
CUS	Creative Urban Spaces
HCC	Historical and Cultural Capacities
M	Mean
OS	Organizational Structure
RMS	Root Mean Square
SRMR	Standardized Root Mean Squared Residual
SD	Standard Deviation
T-test	A statistical test that is used to compare the means of two independent groups
VIF	Variance Inflation Factor

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ORIGINAL RESEARCH PAPER

Career progression for white-collar employees: Waste management industry

N.Z., Mohamed Sabri[1], H. Vasudevan[1,*], P. Venugopal[2], M. Mohamed Saat[2]

[1] *Tun Razak Graduate School, Universiti Tun Abdul Razak, Kuala Lumpur, Malaysia*

[2] *Azman Hashim International Business School, Universiti Teknologi Malaysia*

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ABSTRACT

BACKGROUND AND OBJECTIVES: In the era of globalization, businesses face the challenge of developing and maintaining an effective workforce. Human resource leaders should closely monitor employee discontent with career progression to prevent workplace productivity declines and employee attrition. The primary reason for job loss is often due to a lack of career progression. Career progression involves moving up the corporate ladder, accepting new responsibilities, transferring to better positions, and achieving long-term goals. It refers to the upward or downward movement of employees within an organization, from entry-level to management positions. This study aims to fill knowledge gaps on white-collar occupations, career progression, and how these factors impact salary, lifestyle, and job security.

METHODS: This study used quantitative analysis and hypothesis testing to determine the association between the variables. Data analysis was done using Statistical Software for Social Science (SPSS) software. A total of 250 questionnaires were sent out, of which 231 were returned with feedback, and 227 of those were usable, yielding a 90% response rate.

FINDINGS: Multi-collinear analysis data reveal a negative link between salary and career progression, with a beta coefficient of-0.148 and a p-value of 0.010, which is more than 0.001. Nonetheless, the p-value for job security is less than 0.001, with a beta coefficient of 0.462. The beta coefficient for lifestyle is 0.348, and its p-value is less than 0.001. Hence, the research indicates that lifestyle and job security positively correlate with career progression.

CONCLUSION: The National Solid Waste Management Policy aims to establish a sustainable, integrated waste management system, promote public awareness, and enhance infrastructure for efficient waste management. In line with the study's findings, the policy could be enhanced by incorporating measures that promote employees' lifestyles and career progression.

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*Corresponding Author:
Email: *hemaloshinee@unirazak.edu.my*
Phone: +60126281490
ORCID: 0000-0002-2767-8044

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INTRODUCTION

Prior generations frequently categorized employment based on the collars, shirts, or other clothes that employees typically wore. White-collar professionals, for instance, got their name from the classy white shirts they wore under their business suits (Chatterjee, 2023). Unsuitable settings can suppress natural development, so human resource leaders should monitor employee discontent with career progression to prevent workplace productivity declines and employee attrition. Research indicates that lack of career progression is the primary reason for job loss, according to various studies (Abu-tineh *et al.,* 2023). Many managers and HR professionals mistakenly believe offering more money to employees can solve the 'lack of career progression' problem. Individuals dressed in suits and ties for desk employment, who frequently shun manual labor, are referred to as white-collar workers. Typically, they earn more wages than workers in blue-collar jobs (Khan *et al.,* 2023). The pristine, button-down white shirts that business people wear are referred to as "white collar," a term made popular by American novelist Upton Sinclair in the 1930s. The phrase originated from the requirement that male employees in office buildings in the 19th and 20th centuries almost invariably dress professionally in white collared dress shirts (Bar *et al.,* 2024). The work entails mental rather than physical tasks such as problem-solving, coordination, leading people, and decision-making. Over time, specialized skills and practices are generally expected of white-collar employees. Employees with white-collar jobs must also keep up with the latest advancements and changes in the industry to tailor their strategies (Forsberg *et al.,* 2024; Hanley, 2014). White-collar workers are employed in management, administrative, and clerical positions in office environments (Popova, 2023). Companies that are hiring these personnel frequently need a bachelor's degree or more, as well as comparable industry experience (Lucas *et al.,* 2023). White-collar jobs frequently offer higher earning potential, contingent on additional education (Lopez *et al.,* 2019; Yavas, 2024). Typically, these individuals receive an annual wage (Popova, 2023). White-collar employees typically receive a wage and work Monday through Friday from 9 to 5. A white-collar worker who has regular working hours may make plans for weekends and holidays (Hidasi *et al.,* 2023). Salaried pay is often provided for white-collar occupations, and the employee's overall performance determines it. Prior studies (Bamieh *et al.,* 2020) have acknowledged that companies involved in the services sector tend to have a higher proportion of manager and white collars positions and higher salaries. Previous research has focused on the structured nature of white-collar jobs and how they affect lifestyle choices. This study goes beyond this by investigating the possible advantages of flexible work schedules and the significance of organizational support in improving the health and well-being of white-collar workers. To improve the general well-being of white-collar workers, the study seeks to provide useful insights for both individuals and businesses (Senthanar *et al*., 2020). Studies repeatedly demonstrate that white-collar positions are linked to higher salaries, especially for more experienced professionals and in large organizations (Morton, 1986). The link between salary and profession emphasizes the financial advantages associated with these careers (Ranta *et al.,* 2024). Demerouti and Bakker (2023) stated that relevant tangible resources include information and communication technology (ICT) tools, sufficient rewards as well as career opportunities, and increased job security. In later phases of lifespan perspective, career and job performance may decrease, even while job security, job engagement, and job satisfaction may grow as people advance in their professions owing to developments inside an organization (Alessandri and Borgogni, 2015; Cronin, 2024; Fasbender *et al.,* 2017). Job security is expected to be higher for those with upward mobility, as it is often associated with reduced job insecurity (Green, 2003). Existing literature (Obrenovic *et al.,* 2021) focuses on white jobs and its link with job security. The interplay between career progression and job security is a complex and dynamic process influenced by both individual and organizational factors. White-collar jobs' structured character has been shown to have a major influence on lifestyle; a regular work schedule and professional setting are important contributing aspects (Lee, Kwon, and Paek, 2014). Lifestyle improvements, including healthy living and personal development, are crucial for sustaining work ability and cognitive functioning, particularly as individuals age (Aalbers and Lange, 2015). Because they increase job performance and potential, these enhancements can also result in career progression (McDade, 1990).

Career progression is the movement of employees upward within an organization when progressing from an entry-level position to a management position or moving downward when moving from a management position to an entry-level position (Baral *et al*., 2024). Although everyone's definition of career progression is different, it all starts with setting long-term goals that are subdivided into short-term objectives (Judge, 2023). A few instances of career progression include moving up the corporate ladder, accepting new responsibilities, changing to better positions, and realizing your long-term goals. It is equivalent to developing one's career. The terms of career progression however, might differ from person to person (Bazine *et al.,* 2023; Steindórsdóttir *et al.,* 2023). In the dynamic world of work, the traditional dress-code classification has evolved into a crucial differentiation between white-collar and blue-collar positions. This research determines the impacts of working in white-collar jobs, with a special emphasis on how career progression in these positions affects salary, lifestyle, and job security (Chiarini *et al*., 2023; Liu *et al.,* 2024). Career progression within white-collar employment emerges as a critical dependent variable. Studies repeatedly demonstrate a strong relationship between salary and career progression, especially as people move up the corporate ladder (Ikhenoba *et al.,* 2023). Hence, the identified gaps in the literature regarding salary, job security, and lifestyle within white- collar employment serve as focal points. The research aims to strategically improve knowledge by addressing gaps that have been found in white-collar work, notably about salary, job security, and lifestyle (Sumanth *et al.,* 2014). Sorting previous research results by year, the research starts by acknowledging the historical context of white-collar classifications, with a focus on the 1930s and the impact of Upton Sinclair. This places the term's evolution and significance with professionals in office environments in context. The importance of white-collar workers as assets to companies is emphasized by recognizing the traits of these positions, which include mental duties, specialized skills, and the need to keep updated. The literature analysis then identifies research gaps, emphasizing the necessity for a comprehensive knowledge of salary, job security, and lifestyle in white-collar jobs. This comprehensive overview strategically aligns the study's objectives with identified gaps, ensuring the research contributes significantly to the evolving body of knowledge in white-collar employment dynamics (Sumanth *et al.,* 2014). This study aims to fill knowledge gaps on white-collar occupations, career progression, and how these factors impact salary, lifestyle, and job security in the year 2024.

Literature review

The literature review is a crucial part of the research, examining the dynamics of white-collar workers, their career progression, salary, job security, and lifestyle. The study explores the global and Western connections between white-collar workers' salary, job security, lifestyle, and career progression, highlighting gaps in current knowledge and enhancing understanding for academic discourse and practical organizational settings. Research suggests that higher salaries can positively impact career progression in the waste management industry (Suedekum and Blien, 2007; Kwon, 2006; Bryson *et al.,* 2011; Prince, 2003). Suedekum (2007) found that higher wages can stimulate employment growth, indicating a potentially positive impact on career progression. Kwon (2006) and Bryson (2011) both support the idea that financial incentives, including higher salaries, can motivate workers to excel in their roles and seek promotions. Nevertheless, white-collar professionals engaged in mentally demanding tasks often commit significant time and effort to their roles (Senthanar *et al.,* 2020). This is supported by research showing that salaries can improve worker performance, potentially due to career concerns, higher income, and off-the-job training (Bryson *et al.,* 2011). Prince (2003) further emphasizes the importance of perceived role enhancement opportunities, which could be facilitated by higher salaries, in fostering a positive career trajectory. Similarly, Njoku *et al*., (2023) claim that as individuals ascend the corporate hierarchy, salary becomes not only a compensation measure but also a symbol of recognition, competence, and achievement within the organizational structure. In the waste management sector, competitive salaries may serve as a motivating factor, attracting and retaining skilled professionals. For example, if white-collar workers in waste management are offered higher salaries, they may be more motivated to excel in their roles, seek promotions, and actively contribute to their career advancement. Therefore, salary plays a significant role in fostering a positive

career trajectory among white-collar professionals in this industry. Thus, the following hypothesis is proposed:

H1: There is a positive relationship between salary and career progression among white-collar workers in the waste management industry.

According to Demerouti and Bakker (2023), the structured nature of white-collar jobs, with clearly defined roles and career paths, is linked to enhanced job security. This predictability and stability can lead to increased organizational commitment and reduced job insecurity (Furåker and Berglund, 2014). Accordingly, research suggests that job security can have a positive impact on the career progression of white-collar workers in the waste management sector (Jiang, 2017). This is supported by the finding that job security can enhance job satisfaction, reduce stress, and provide employees with the confidence to invest in their professional development (Loi *et al.,* 2012). In addition, job security may lead to a focus on long-term career goals, leadership roles, and progression opportunities within the industry (Berntson *et al.,* 2010). Trust in management can also play a crucial role in mitigating the negative consequences of job insecurity (Anand *et al.,* 2023; Shoss et *al.,* 2023). In the context of waste management, where stability and continuity are crucial, white-collar workers who perceive their jobs as secure may be more likely to focus on long-term career goals, take on leadership roles, and pursue opportunities for career progression within the industry. This is particularly important in the context of sustainable human resource management and the sustainability of careers, where continuity is crucial (De Vos and Van der Heijden, 2017). Furthermore, white-collar workers in this industry are interested in ongoing education and training, indicating a desire for career progression (Dymock *et al.,* 2012). Hence, job security plays a significant role in fostering a positive career trajectory among white-collar professionals in this industry. Thus, the following hypothesis is proposed:

H2: There is a positive relationship between job security and career progression among white-collar workers in the waste management industry.

A range of studies supports the hypothesis that a favorable lifestyle, including work-life balance, flexible arrangements, and well-being initiatives (Nishi *et al.,* 2016; Bjärntoft *et al.,* 2020; Lee *et al.,* 2014) can positively impact the career progression of white-collar workers in the waste management industry. Nishi *et al.,* (2016) found that personal lifestyle factors such as diet, exercise, and sleep can enhance work engagement. Bjärntoft *et al.,* (2020) identified specific occupational and individual factors, such as over-commitment and boundary management, that can influence work-life balance, with perceived flexibility at work playing a key role. Lee *et al.,* (2014) further emphasized the importance of lifestyle, particularly leisure activity and regular exercise, in improving the mental health of white-collar workers. Lastly, Hayman (2010) highlighted the positive impact of flexible work schedules, such as flextime, on job satisfaction and work-life balance. These findings collectively suggest that a conducive lifestyle can indeed contribute to the career progression of white-collar workers in the waste management industry. For example, if white-collar workers in waste management are provided with opportunities for a balanced lifestyle, they may be more likely to invest in their careers, demonstrate increased commitment to their roles, and pursue career progression within the industry. Hence, lifestyle plays a significant role in fostering a positive career trajectory among white-collar professionals in this industry. Thus, the following hypothesis is proposed:

H3: There is a positive relationship between lifestyle and career progression among white-collar workers in the waste management industry.

Materials and Methods

Survey design and data collection

This study applied non-probability sampling methods, like convenience sampling, which might not have reflected the whole demographic context and might have been used for specific populations rather than generalizability (Setia, 2016). This method was often used in descriptive studies because of its quick turnaround times and inexpensive cost, which enabled researchers to collect large amounts of data in a short length of time and easily reachable (Vindrola-Padros and Johnson, 2020). Since this study uses convenience sampling, which is non-probability and involves selecting samples from those that are easily accessible while being fully aware that the samples may not accurately represent the entire population. The sample size for this study was determined by Gill *et al.,* (2010) using a desired accuracy and a 95% confidence level. Out of 50,794 workers in Malaysia's

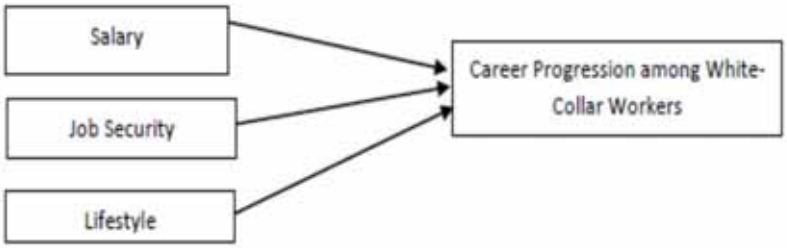

Fig. 1: Conceptual framework of salary, job security, and lifestyle on career progression among white-collar workers

waste management sector overall. Consequently, 217 was the sample size that was employed. This could have been used to identify white-collar workers who were employed by Malaysia's waste management industry. Since the study's focus was on white-collar workers in Malaysia's waste management industry and its population was primarily made up of white-collar employees, the study's unit of analysis was individuals (Cyr, 2016). The Department of Statistics Malaysia reported that as of 2021, there were 50,794 workers in Malaysia's waste management sector. Primary sources related to social groups whose opinions on the themes could be preferred, such as questionnaires and focus groups, were one way to collect data; secondary sources could be found in publications, reports, and other sources (Baye *et al.,* 2020). Considering that questionnaires were the most reliable and efficient quantitative method for this study, questionnaires were sent to the intended respondents (Aithal and Aithal, 2020). Furthermore, this study utilized self-administered online surveys, wherein participants were provided with browser access to complete the survey at their convenience and without any disruption. The questionnaire's overall structure is straightforward and engaging, featuring guidelines, an appropriate introduction, and a well-structured questionnaire (Boparai *et al.,* 2019). A five-point Likert scale with the following scales,

1- strongly disagree,
2- disagree,
3- average,
4- agree,
5- strongly agree

was used to design the questionnaires (Cooper and Schindler, 2018). Every element of the questionnaire was carefully examined in the context of the research on the Malaysian waste management sector. The data analysis technique uses Statistical Software for Social Science (SPSS). Primary sources related to social groups whose opinions on the themes could be preferred, such as questionnaires and focus groups, were one way to collect data; secondary sources could be found in publications, reports, and other sources (Baye *et al.,* 2020). Considering that questionnaires were the most reliable and efficient quantitative method for this study, questionnaires were sent to the intended respondents (Aithal and Aithal, 2020). Furthermore, this study utilized self-administered online surveys, wherein participants were provided with browser access to complete the survey at their convenience and without any disruption (Manuilskaya and Vyrskaya, 2019). The measurement items are indicated in Table 1.

Analytical framework

Fig. 1 illustrates the conceptual framework of this study. The conceptual framework of this study delves into the intricate dynamics between salary, job security, lifestyle, and career progression among white-collar workers. The literature review offers theoretical foundations and empirical insights, unveiling existing gaps and forming the groundwork for the conceptual framework. The study categorizes salary, job security, and lifestyle as independent variables influencing the dependent variable, career progression. The framework acknowledges the complexity of these variables, considering various elements that may impact each independent variable. The study suggests linkages, emphasizing the interconnectedness of salary, job security, lifestyle, and career progression. The final demonstration of the conceptual framework aligns the identified variables with the study's objectives. The proposed model draws upon established theories like Expectancy Theory, Social Exchange Theory, Life-

Table 1: Measurement items

Variable	Items	Source	Likert Scale
Salary	S1: I believe my salary is fair given my responsibilities and the nature of my work. S2: I feel that my salary is appropriate for my skills and contributions S3: I am satisfied with the amount of salary I receive for the work I do. S4: I feel that my salary adequately reflects the efforts I put into my job. S5: I feel my salary is competitive compared to others with similar jobs.	OJO and OLAJUMOKE (2023)	5-Likert Scale
Job Security	J1: I feel confident about the security of my job. J2: I believe I will keep my job shortly. J3: I will be employed for a long time in my present workplace. J4: I view my workplace as secure in every respect.	Rao and Shailashri (2023)	5-Likert Scale
Lifestyle	L1: I experience fulfilment in my work L2: I maintain a healthy balance between work and non-work life. L3: I successfully prioritize between work and family responsibilities. L4: I effectively cope with stressors related to work. L5: I experience a supportive and fair work environment.	Clarke *et al.,* (2008)	5-Likert Scale
Career Progression	C1: I am goal-oriented for continuous career growth. C2: I am confident in my skills for my career goals. C3: I seek advice from mentors to navigate my career path. C4: I prioritize tasks to achieve progress in my career. C5: I understand my career interests C6: I demonstrate leadership qualities to lead my career.	Smismans *et al.,* (2021)	5-Likert Scale

Span Theory, and Career Development Theory (Eerde, and Thierry, 1996; Savickas, 1994). These theories offer a theoretical foundation for understanding the relationships among salary, job security, lifestyle, and career progression (Reinharth and Wahba, 1975; Walumbwa, Cropanzano and Goldman, 2011; Höchli, Brügger, and Messner, 2018). Expectancy Theory provides insights into the motivational aspects of salary and career progression (Wabba and House, 1974). In the context of this study, salary serves as a crucial factor influencing career progression, as employees may perceive a direct correlation between their performance, financial rewards, and career progression opportunities (Hemamalini and Washington, 2014). Social Exchange Theory illuminates the reciprocal relationships between job security and career progression, emphasizing the dynamics of give-and-take (Jepsen and Rodwell, 2010). Job security becomes a resource provided by the organization in exchange for the employee's commitment and contribution (Hur *et al.,* 2020). Life-Span Theory contributes by elucidating the evolving nature of individuals' lifestyles and career trajectories over their entire lifespan (Morrison, 2012). Career Development Theory explores the multifaceted process of career choice and progression, considering internal and external factors that shape individuals' vocational journeys (Murugami and Nel, 2012). This comprehensive framework aims to contribute to a nuanced exploration of the factors influencing career progression among white-collar workers, aligning with the comprehensive nature of the study.

RESULTS AND FINDINGS

Descriptive statistics and analysis for variables entering the analysis

The age range is divided into four groups: 18–30, 31–40, 41–50, and 50 years and older. Table 2 shows that the majority of respondents (63.0%, n = 143) were between the ages of 18 and 30. Next in line were those between the ages of 31 and 40 (26.4%, n = 60), 41 to 50 (4.8%, n = 11), and 5.3% (n = 12) who were 50 and above. The three categories of high school, undergraduate, and graduate education make up the

Table 2: Result of the respondent's profile

Demographic		Categories	Frequency (n=227)	Percentage (%)
Age		18-30	143	63.0
		31-40	60	26.4
		41-50	11	4.8
		50 and above	12	5.3
Complete Background	Education	High School	9	4.0
		Undergraduate	140	61.7
		Graduate	77	33.9
Year of Service		Less than 1 year	47	20.7
		2-5 years	100	44.1
		6-9 years	50	22.0
		10 years and above	29	12.8
Job Position Level		*Non-Executive Assistant*	41	18.1
		Executive & Above	227	81.9

complete educational background. Table 2 shows that 61.7% of respondents (n = 140) had an undergraduate degree, with graduate degree respondents following behind at 33.9% (n = 77) and high school respondents at 4.0% (n = 9). The duration of service is divided into four categories: less than 1 year, 2 to 5 years, 6 to 9 years, and 10 years and above. Table 2 shows that the majority of respondents (44.1%, n = 100) have had 2–5 years of service. These are followed by respondents with 6-9 years of service (22.0%, n = 50), those with less than 1 year of service (20.7%, n = 47), and 12.8% (n = 29) who have had 10 years or more of service. There are two categories for job position level classification: executive and non-executive. Table 2 shows that 18.1% of respondents (n = 41) are non-executive, while the majority of respondents (81.9%, n = 186) are executive.

Reflective measurement model results

Reliability analysis

The part on measurement model assessment contains more analysis. A reliability test was carried out to determine each variable's Cronbach's alpha to evaluate internal consistency. Cronbach's alpha has an acceptable range of 0.7 to 0.9, indicating strong reliability. Findings will be more credible if the value is greater than demonstrating how the variables were positively associated with one another (Shiau *et al.,* 2019). In this research, Cronbach's Alpha values range from 0.628 to 0.897 based on Table 3, demonstrating high dependability and adherence to the rule of thumb.

Multiple regression analysis

The study employed multiple regression analysis to ascertain the correlation between the independent factors, namely salary, job security, and Lifestyle, and the dependent variable, Career Progression. Whether to accept or reject the put-out hypotheses will be determined by the results of the multiple regression analysis. According to Copper and Schindler (2018), the independent variables in the regression model can explain the variation percentage of the dependent variable using the R2 metric, which gauges the degree of fit. By taking into account the number of independent variables in the regression model, the adjusted R2 avoids overestimating the impact of adding an independent variable on the quantity of variability captured by the estimated model (Plonsky *et al.,* 2018). According to Zikmund *et al.,* (2016), the adjusted R2 is thought to offer the most accurate estimation of the degree of shared variation once a strong association between the variables has been established. Based on Table 4, with a multiple correlation coefficient (R) of 0.675, the regression analysis results show a strong positive association between the dependent variable (career progression) and the independent variables (lifestyle, salary, and job security). Given their high R-value, it is likely that these indicators together have a major effect on career progression. These three factors account for roughly 45.6% of the variance in Career Progression, according to the coefficient of determination (R2) of 0.456. This high percentage suggests that factors such as lifestyle, salary, and job security have a significant role

Table 3: Result of the reliability analysis

Construct	No. of Item	Item	Reliability Test
CareerProgression	6	I am goal-oriented for continuous career growth.	0.852
		I am confident in my skills for my career goals.	0.816
		I seek advice from mentors to navigate my career path.	0.851
		I prioritize tasks to achieve progress in my career.	0.828
		I understand my career interests.	0.840
		I demonstrate leadership qualities to lead my career.	0.832
Salary	5	I believe my salary is fair given my responsibilities and the nature of my work.	0.855
		I feel that my salary is appropriate for my skills and contributions.	0.880
		I am satisfied with the amount of salary I receive for the work I do.	0.892
		I feel that my salary adequately reflects the efforts I put into my job.	0.884
		I feel my salary is competitive compared to others with similar jobs.	0.897
Job Security	4	I feel confident about the security of my job.	0.697
		I believe I will keep my job in the near future.	0.647
		I will be employed for a long time in my present workplace.	0.628
		I view my workplace as secure in every respect.	0.681
	5	I experience fulfilment in my work.	0.790
Lifestyle		I maintain a healthy balance between work and non-work life.	0.696
		I successfully prioritize between work and family responsibilities.	0.669
		I effectively cope with stressors related to work.	0.685
		I experienced a supportive and fair work environment.	0.690

in determining how far along a person's career will go within the study population. This model's robustness is further supported by the modified R2 value of 0.448, which shows that about 44.8% of the variability in Career Progression is still explained by these factors even after considering the number of predictors. With a standard error of 0.42580, the model's predictions are, on average, 0.42580 units off from the real Career Progression values, showing a reasonable level of accuracy. The regression model's residuals are tested for autocorrelation using the Durbin-Watson statistic, which has a value of 1.471. Although there should be no autocorrelation, a value of 1.471 indicates some positive autocorrelation, however, not enough to rule out the model. The optimum value is about 2. In general, the model offers a solid and trustworthy explanation of career progression based on salary, job security, and lifestyle

Correlation matrix

The linear relationship between the variables is shown using a correlation matrix (Ozdemir *et al.,* 2019). According to Zikmund *et al.,* (2016), a correlation value of more than 80% suggests the presence of a multicollinearity problem; strong multicollinearity reduces validity and can lead to skewed study conclusions. The correlation matrix is shown in Table 5, with a value range of 0.215 to 0.642; all of the independent variables in the questionnaire are connected. Job Security had the highest correlation, 0.615, between the independent and dependent variables.

Regression ANOVA

According to Hair *et al.*, (2019), regression analysis of variance (ANOVA) is a statistical technique that compares the variances of two or more independent variables on a dependent variable and shows a significant association when the p-value is less than 0.05 at the 95% confidence level. If the p-value is higher than 0.05, the null hypothesis should not be disproved because the evidence against it is so weak

Table 4: Multiple regression analysis

Model Summary[b]					
Model	R	R Square	Adjusted RSquare	Std. Error of the Estimate	Durbin-Watson
1	.675[a]	.456	.448	.42580	1.471

a. Predictors: (Constant), Lifestyle, Salary, Job Security
b. Dependent Variable: Career Progression

Table 5: Correlation matrix

Correlations					
		Career Progression	Salary	Job Security	Lifestyle
Career Progression	Pearson Correlation	1			
Salary	Pearson Correlation	.215**	1		
Job Security	Pearson Correlation	.615**	.480**	1	
Lifestyle	Pearson Correlation	.585**	.408**	.642**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6: Regression ANOVA

ANOVA[a]						
	Model	Sum of Squares	df	Mean Square	F	*Sig.*
1	Regression	33.844	3	11.281	62.224	*<.001*[b]
	Residual	40.430	223	.181		
	Total	74.274	226			

a. Dependent Variable: Career Progression
b. Predictors: (Constant), Lifestyle, Salary, Job Security

(Smith, 2018). The regression ANOVA results show there is a statistically significant link between the predictors (Lifestyle, Salary, and Job Security) and the dependent variable (Career Progression), as indicated by the p-value in ANOVA Table 6, which is 0.001. This indicates that at least one predictor significantly influences career progression and that the regression model fits the data well.

Multicollinearity analysis

According to Bougie *et al.*, (2019), the beta coefficient generally indicates that a number nearer 1 indicates that the independent variable will have a higher influence on the dependent variable, whilst a value of 0 indicates that the dependent variable would not significantly affect the study. According to Table 7, both standardized and unstandardized coefficients are included in the model. The constant term (intercept), which stands for the Career Progression baseline level at which all predictors are zero, is 1.987. For every unit change in each predictor, the unstandardized coefficients give the raw change in the dependent variable. In particular, Salary's unstandardized coefficient is -0.095, meaning that when all other variables are held constant, Career Progression falls by 0.095 units for every unit increase in Salary. With a t-value of -2.608 and a p-value of 0.010, this negative association is statistically significant, indicating that salary has a small but substantial inverse link with career progression. An increase of one unit in Job Security is correlated, holding other variables constant, with an increase of 0.324 units in Career Progression, according to the unstandardized coefficient of 0.324 for Job Security. With a t-value of 6.815 and a p-value of less than 0.001, this positive connection is highly significant. With a standardized coefficient (Beta) of 0.462, Job Security is the predictor in the model that has the biggest effect on Career Progression in comparison to the other predictors. Similarly, the unstandardized coefficient for lifestyle is 0.276, meaning that for every unit increase in lifestyle, there is a corresponding increase in career progression of 0.276 units. With a p-value of less than 0.001 and a t-value of 5.341, this association

Table 7: Coefficients

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.987	.160		12.423	<.001		
	Salary	-.0.95	.036	-.148	-2.608	.010	.753	1.328
	Job Security	.324	.048	.462	6.815	<.001	.531	1.885
	Lifestyle	.276	.052	.348	5.341	<.001	.574	1.741

a. Dependent Variable: Career Progression

is likewise very significant. Though much less so than Job Security, the standardized coefficient for Lifestyle is 0.348, indicating that it too has a significant impact on Career Progression. Multicollinearity among the predictors is evaluated using collinearity statistics, such as Variance Inflation Factor (VIF) and Tolerance. A VIF value of less than 10 and tolerance values near 1 suggest no discernible multicollinearity. Within this model, the tolerance values for salary are 0.753 and 1.328, for job security they are 0.531 and 1.885, and for lifestyle, they are 0.574 and 1.741. These figures imply that multicollinearity is not a significant issue for this model. Overall, the results of the regression analysis show that, although salary has a negative impact, lifestyle and job security both considerably and favorably affect career progression, with job security having the largest impact. The model is strong and offers insightful information about the variables influencing Career Progression in the population under study. Table 7 indicates that the previous equation can be expressed as follows:

y = 1.987− 0.95 X1+ 0.324 X2 + 0.276 X3

where:

y = Career Progression among white-collar employees

X1 = Salary,

X2 = Job Security,

X3 = Lifestyle.

Discussion of results

The research's main finding (H1) is that there is an insignificant relationship between salary and career progression among white-collar workers in the waste management industry. The analysis's findings indicated that the salary's beta coefficient is -0.148 and that its p-value is 0.010, which is more than 0.001. The salary and career progression do not exhibit a significant association because the p-value is more than 0.001. This result directly answers the research question regarding the extent to which salary impacts career progression in this sector. Higher salaries in this industry may not always translate into better prospects for career progression (Viljoen *et al.,* 2016). The key finding of this study is the inverse relationship between salary and career progression. This implies that, in comparison to lower-salary individuals, those with higher salaries in the waste management sector would have fewer prospects for upward mobility. (Woolston, 2016). This study raises important questions, such as the necessity of taking industry-specific factors into account when examining career progression, and also contradicts accepted knowledge (Hüttges and Fay, 2015). The findings are noteworthy because they shed light on the dynamics of careers in the waste management sector and indicate that salary is not a reliable indicator of career progression (Blundell *et al.,* 2020). To progress in their careers, employees may need to concentrate on issues other than salary, and employers may want to take into account how salary structures affect employee motivation and career progression (Pérez and Sabelis, 2019). The research's H2 is that there is a positive relationship between job security and career progression among white-collar workers in the waste management industry. According to the analysis's findings, the job security's beta coefficient is 0.462, and its p-value is less than 0.001. There was a substantial positive correlation between job security and career progression; that is, for every unit increase in job security, career progression will increase by 0.462. Thus, H2 is supported. This implies that career progression in the waste management sector is more common among white-collar employees who believe their jobs are secure. The results make it abundantly evident that career progression is greatly aided by job security. The results corroborate the findings of

Table 8: Summary of Testing

Research Question	Hypothesis	Results
To what extent does the salary have a relationship with career progression among white-collar workers in the Malaysian environmental service industry?	There is a positive relationship between salary and career progression among white-collar workers in the waste management industry.	Not supported
To what extent does job security have a relationship with career progression among white-collar workers in the Malaysian environmental service industry?	There is a positive relationship between job security and career progression among white-collar workers in the waste management industry.	Supported
To what extent does the lifestyle have a relationship with career progression among white-collar workers in the Malaysian environmental service industry?	There is a positive relationship between lifestyle and career progression among white-collar workers in the waste management industry.	Supported

previous research studies by Anand *et al.,* (2023), which also found a favorable relationship between career progression and job security in various circumstances. According to the research Haq *et al.,* (2023), job security gives workers the steadiness and self-assurance they need to concentrate on their long-term professional objectives. The researcher's H3 is that there is a positive relationship between lifestyle and career progression among white-collar workers in the waste management industry. According to the analysis's findings, the lifestyle's beta coefficient is 0.348, and its p-value is less than 0.001. Career progression and lifestyle have a strongly positive association, meaning that for every unit increase in lifestyle, career progression will improve by 0.348. Thus, H3 is supported. It is suggested in the conclusion that white-collar individuals who keep a healthy and balanced lifestyle are more likely to see career growth in the waste management industry, since lifestyle has a substantial beneficial impact on career progression. The results demonstrate that lifestyle elements, including mental and physical health, have a major impact on career progression. The summary of testing has been presented in Table 8

Practical and policy recommendation

A thorough foundation for efficiently managing solid waste is provided by the National Solid Waste Management Policy (NSWMP). Expanding this strategy would be a good way to deal with the results of this study, which show that among white-collar workers in the waste management sector, lifestyle characteristics positively correlate with career advancement. These results can be incorporated into the policy to support a more comprehensive approach to waste management that takes career development and employee well-being into account. Developing an integrated and sustainable solid waste management system, encouraging public knowledge and engagement in appropriate waste management practices, and improving infrastructure and services to enable efficient waste management are some of the main objectives of the National Solid Waste Management Policy. This policy can be improved by adding certain measures that promote employees' lifestyles and career progression in light of the study's conclusions. These actions could include offering wellness programs and mental health support services, implementing flexible work schedules to enhance work-life balance, and providing chances for ongoing learning and development to support career progression (Kossek *et al.,* 2017). A more robust workforce and better control over career progression as a key strategic resource for the industry will be made possible by increased organizational support for work-life balance and individual well-being. Considerable progress is anticipated in the future about the sustainability of the sector. All parties, such as employers, policymakers, and employees, will receive an equitable share of these benefits.

Limitation and future recommendation

Even though the present study contributes to the existing body of knowledge, it also has some limitations. First, only white-collar employees in the waste management sector were included in the study due to time constraints. Lengthening the study and broadening the pool of respondents are suggested ways to improve the comprehensiveness of subsequent research. Thus, a comprehensive understanding

of the elements impacting career growth would be achieved by involving individuals from various industry sectors, such as top managers and blue-collar workers. Secondly, the present investigation utilized a quantitative research methodology. Future studies could think at using a mixed-method or qualitative approach to acquire a deeper understanding of the nuances of how lifestyle affects career progression. Compared to cross-sectional research, longitudinal studies would be useful for tracking changes and trends over time, offering a more dynamic picture of career progression. Focus groups and interviews can produce rich, comprehensive data that quantitative approaches might miss. Thirdly, SPSS was used in this study to analyze the data. Incorporating sophisticated tools such as SMART PLS3, SAS, NVIVO, and AMOS could improve the analysis's robustness in subsequent studies. A deeper understanding of the interactions between variables would be possible with the use of these tools, which would also enable the inclusion of moderating and mediating variables and more advanced econometric methodologies. By using these sophisticated methods, it may be possible to find new insights and improve the accuracy of the findings. Fourthly, extending the study's reach beyond a specific location is essential to generalizing its findings. To provide a more representative and diverse sample, data from other locations or countries should be gathered for future research. The accuracy and dependability of the data gathered would be increased by using a group of skilled enumerators to perform face-to-face interviews in various locations. Additionally, this method would aid in identifying regional and cultural variations that could impact career progression in the waste management sector.

CONCLUSION

The primary goal of this research is to determine the correlation between the dependent variable career progression and the independent variables salary, job security, and lifestyle among Malaysia's white-collar employees in the waste management sector. For the aim of achieving the goal, three objectives were created. Through the distribution of questionnaires to the 250 white-collar workers in Malaysia's waste management industry, the analysis may be used to address the goals that were achieved. The conceptual framework was built as a result of the numerous literature reviews presented. After meeting those aims, three hypotheses were developed, which will be discussed in more detail in this study. The findings show that despite the common perception that higher salaries lead to better career progression, the data indicate otherwise for the waste management industry. The results of this analysis differ from those of research by Smith (2020) and Johnson and Lee (2018), which discovered a positive association between salary and career progression in other sectors. This disparity highlights the special characteristics of the waste management sector. The results show that high salaries are not always correlated with progression in one's profession, which adds new information to the subject. Workers who can lead healthy lifestyles typically focus on professional growth, take on greater responsibility, and perform better at work, all of which contribute to career progression (Ryan *et al.,* 2023). The results support the notion that a well-maintained lifestyle creates an environment that is favourable for career progression. The results are in line with earlier research, which discovered that leading a healthy lifestyle helps one's career progression and that leading a healthy lifestyle has a positive impact on professional development and career success in a certain industry, specifically the waste management sector. The study's contribution and potential directions for future research were also emphasized. According to the research, career progression is significantly and favorably impacted by lifestyle and job security. The need for firms to develop encouraging work cultures that strike a balance between work and personal life is highlighted by this research. In this regard, developing and ensuring continuous growth in the manufacturing sector is among the main agendas for Malaysia. In addition, the importance of ensuring a good working environment is very necessary so that the productivity of the workforce will be better and more productive. Work environment means the processes, systems, structures, or conditions in the workplace that have a positive impact on the productivity of the workforce. The work environment also includes policies, regulations, culture, resources, work relationships, work location and internal and external factors of the work environment that influence the way employees carry out their respective tasks. Relationships with colleagues include relationships with employees who are at the same hierarchical level and do

not have authority over each other. Maintaining employer-employee relationships that contribute to satisfactory productivity, motivation, and morale among employees should be a focus for every organization. Psychosocial support in relationships between employees is capable of creating high work productivity among employees where conditions will help the work process to be carried out smoothly and more perfectly.

AUTHOR CONTRIBUTIONS

N.Z. Mohamed Sabri performed the literature review and experimental design and analyzed and interpreted the data, and H. Vasudevan, P. Venugopal, and M. Mohamed Saat prepared the manuscript text and manuscript edition. N.Z. Mohamed Sabri and H. Vasudevan performed the experiments and literature review, compiled the data, and prepared the manuscript. N.Z. Mohamed Sabri performed the data analysis and findings, while H. Vasudevan compiled the data analysis and findings for the manuscript edition.

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CONFLICT OF INTEREST

The authors declare that no potential conflicts of interest in publishing this work. Furthermore, the authors have witnessed ethical issues such as plagiarism, informed consent, misconduct, data fabrication, double publication or submission, and redundancy.

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ABBREVIATIONS

$\bar{Y}$	Average of observed data
R^2_{adj}	Adjusted coefficient of determination
$\bar{Y}$	Average of observed data
AVE	Average variance extracted
R^2	Coefficient of determination
CAGR	Compound Annual Growth Rate
H	Hypothesis
ICT	Information and Communication Technology
$\propto$	Level of significance
NSWMP	National Solid Waste Management Policy
p-value	Probability value
r	Pearson correlation coefficient
r-value	Pearson correlation coefficient
SPSS	Statistical Software for Social Science
VIF	Variance Inflation Factor

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ORIGINAL RESEARCH PAPER

Monetary stability and its role in SDG implementation: Identifying socio-economic and renewable energy challenges in G20 countries

N. Prawoto[1,*], A. T. Basuki[1], A. Munifatussaidah[2], I. Q. Ayun[3]

[1] *Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta, Special Region of Yogyakarta, Indonesia*

[2] *Faculty of Economics and Business, Universitas Gadjah Mada, Special Region of Yogyakarta, Indonesia*

[3] *Faculty of Economics and Business, Universitas Ahmad Dahlan, Special Region of Yogyakarta, Indonesia*

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ABSTRACT

BACKGROUND AND OBJECTIVES: The Sustainable Development Goals show the development goals that would determine the needs of future generations. This research intends to look at the role of monetary stability and exchange rates on the main pillars of the Sustainable Development Goals.

METHODS: The research uses panel data regression techniques on secondary data sourced from the Sustainable Development Goals, World Bank, International Monetary Fund, and Organization for Economic Co-operation and Development data in the Group of Twenty countries from 2010-2022. The model assesses the relationship between monetary stability toward the economic, social, and environmental pillars of the Sustainable Development Goals.

FINDINGS: The findings show that monetary stability significantly affects all tested variables, with Gross Domestic Product per capita (β = 15.302; ρ = 0.000), unemployment (β =-0.755; ρ = 0.000), trade openness (β = 110.078; ρ = 0.000), poverty (β = 16.566; ρ = 0.000), GINI Index (β = 0.436; ρ = 0.000), carbon emissions (β =-3.242; ρ = 0.000), and renewable energy usage (β =-34.739; ρ = 0.000) is negatively influenced, thus supporting each hypothesis. This suggests monetary stability has dominant direct economic and environmental impacts.

CONCLUSION: The implications to be brought forward by this research are expected to empirically represent a solution to the challenges in accomplishing the three primary pillars of the Sustainable Development Goals from the standpoint of exchange rate stability and macroeconomic monetary policy.

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*Corresponding Author:
Email: *nanopra@umy.ac.id*
Phone: +62 8164272479
ORCID: 0000-0001-7895-8911

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INTRODUCTION

The global agenda for 2030, also known as the Sustainable Development Goals (SDGs), is a commitment that accelerates several countries towards a unified synergy in their policies. Such policies of the SDGs are the same for all countries concerned (Bansal *et al.*, 2021). SDGs can meet the needs of current and future generations (Miroshnichenko and Brand, 2021). Ermelena in Risanti *et al.* (2020) pointed out that there are three important elements in the SDGs known as the PG3, namely the Planet, People, and Partnership, which act as a barometer on how the SDGs affect human quality. Therefore, the achievement of the SDGs pillar will overcome problems such as reducing economic inequality, as well as supporting the enhancement of the standard of environmental welfare, health, and education. SDGs are formed to have main pillars, namely social, economic, and environmental, which can be driven by advances in monetary policy and financial stability (Inglesi-Lotz and Bohlmann, 2023). One factor determining sustainable economic development is monetary policy through the contribution of monetary transmission (Wang *et al.*, 2023). This monetary transmission is used as a highly effective parameter to control price stability and economic growth (Priya and Sharma, 2024). Monetary transmission can also reduce poverty through interest rate policy on easy access to business capital for the community, particularly for Small and Medium Enterprises (SMEs) (Cape *et al.*, 2019). Financial stability reflects the health of the exchange rate system that can withstand financial shocks that will disrupt the country's economic cycle (Chugunov *et al.*, 2021). Therefore, exchange rate stability will emphasize the resilience of the financial system to continue to play a role that can mediate economic activity between countries (Oanh *et al.*, 2023). Economic, social, and environmental conditions are important worldwide concerns, especially when the COVID-19 pandemic hits and will continue post-pandemic or during the economic recovery period. All countries pay special attention to sustainable economic and social conditions. Globally, economic conditions have improved over the past five years, even though during 2020-2021 the COVID-19 pandemic resulted in a global recession with economic growth recorded at negative 4% (WorldBank, 2021). Then, the economic recovery in 2022-2023 increased to an average of 2-3%, one of which was due to monetary control policies ranging from interest rate adaptation and control supply (addition, in terms of social development, poverty is one of the biggest issues faced by the majority of countries, during the last five years of 2019-2022, the global poverty rate has decreased with a recorded figure of 9.6% to 8.4% (OWD, 2022). Not only economic and social, but also environmental conditions are currently a concern for all countries, starting from the problem of climate change and the use of energy resources needed by the country. According to Murshed *et al.*, (2023), Emissions (CO2) can be controlled by contractionary monetary policy to achieve environmental sustainability, in addition to maintaining exchange rate stability can increase consumption of renewable energy. Thus, in addressing key issues related to sustainable development, solutions are needed in the form of maintaining international financial stability and monetary policy to mitigate global economic uncertainty, social inequality, and global climate change. A review of previous studies shows that the correlation between monetary stability and SDGs is economic development (Al khatib, 2023; Arintoko and Kadarwati, 2022; Golpe *et al.*, 2023; Rahman *et al.*, 2019; Cyclos, 2023), in reducing poverty and improving the quality of human resources (Mustafa, 2020; Saeed, 2020), and support environmental stewardship, such as efforts to reduce climate change risk (D'Orazio and Popoyan, 2023; Hashmi *et al.*, 2022; Inglesi-Lotz and Bohlmann, 2023). Most previous studies have examined various groups of countries in the world, such as the Association of Southeast Asian Nations (ASEAN), the Asian region, Africa, Europe, and the Americas. Therefore, this study tried to research a group of countries based on the Group of Twenty (G20) forum, consisting of 19 countries, the European Union, and the African Union. G20 countries represent cooperation between countries that have goals in the main issues related to SDGs (G20, 2023). One solution is through the role of the monetary sector and international financial stability policies between each G20 country (Ministry of Education and Culture, 2022). The economic condition of the majority of G20 countries above the world economy is recorded at an average of 4-5% (OECD, 2022). The post-COVID-19 pandemic caused unprecedented economic disruptions, including sharp GDP contractions, rising unemployment,

inflationary pressures, and supply chain disruptions. In response, G20 nations implemented coordinated monetary and fiscal policies to stabilize financial markets, support economic recovery, and mitigate long-term economic scarring (G20, 2023). Despite extensive studies on SDGs and financial stability, limited research specifically examines the role of monetary stability in achieving SDG targets within G20 nations. Existing studies often focus on regional or country-specific contexts, overlooking the global financial interdependencies among these economies. This shows that by conducting research related to the role of international monetary and financial stability in realizing sustainable development in G20 countries, it is expected to represent global SDGs empirically and become an effort to implement the three main pillars of SDGs (social, economic, and environmental). This research is expected to complement previous research by expanding the study of SGDs based on an empirical analysis approach.

Review of literature

SDGs

SDGs were instituted by the United Nations Development Program (UNDP), following the end of the Millennium Development Goals, or what is more commonly known as the era called the MDGs. They included new goals that are more universal, integrated, and multi-dimensional (Johnston, 2016). Sustainability, which is a key principle of the SDG framework, integrates economic, social, and environmental contexts. These are configured in 17 goals and 169 targets, which are formulated into several objectives, each with an array of indicators. Hence, 17 goals stand as a global approach to a better sustainable world (UNDP, 2022). The goals of the SDGs are represented by three main pillars, namely economic, social, and environmental (Boar *et al.*, 2020). To begin with, the economic pillar seeks to attain quality economic growth through industrial inclusion and innovation, provision of sustainable employment opportunities, development of good infrastructure and clean energy, and global partnerships. This facilitates effective long-term growth associated with low price levels. By reducing interest rate levels, economic development will be catalyzed. The contribution of monetary policy towards sustainable development is the containment of price level changes. Second, the social pillar essentially aims to fulfill the basic quality of equitable human rights to achieve the welfare of society and the community. In addition, the sustainable social pillar is focused on creating an inclusive society, reducing inequality, ensuring long-term prosperity, and maintaining social harmony and justice. To realize the social pillar by implementing systems and policies that can reduce social issues, such as the implementation of policies that provide access and opportunities in terms of price stability, which are expected to be accessible to the community, to reduce social gaps. Third, the environmental pillar aims to achieve the preservation of natural resources and an environmentally friendly lifestyle to support a better human life. Some environmental issues, such as air pollution, water, soil, climate change, and excessive exploitation of natural resources, then every country needs solutions that can create a maintained and sustainable environment. Solutions such as reducing gas emissions, increasing the production and use of renewable energy, raising awareness, and engaging all earthlings to sustainably preserve and manage resources now and in the future (Eisenmenger *et al.*, 2020; Swain and Yang-Wallentin, 2020; UNDP, 2022).

Monetary stability

Monetary policy is a macroeconomic policy from the demand side. This policy is carried out by the central bank to achieve various macroeconomic objectives such as price level stability, increasing the country's national income, and fulfilling employment, smooth consumption, and other macroeconomic problems (Hughen and Beyer, 2015). Monetary policy refers to a course of action undertaken by the government of a country with control over the money supply, broad money, and interest rates. The policy of raising or lowering interest rates and the money supply is known as expansionary or contractionary monetary policy (Fu *et al.*, 2023). In each country, monetary policy has a broad role, so the central bank tries to design to meet the needs of the country, where monetary policy cannot be separated from the aim of achieving the country's development (Srithilat and Sun, 2017).

Review of previous research

Based on the background and literature, this study also refers to previous research on monetary policy issues about the stability of exchange rates,

with three pillars of sustainable development goals: economic, social, and environmental. Siklos (2023) found that monetary policy as measured by the growth of the money supply, balance of payments, and determination of interest rates in each country had a significant and positive effect on economic growth measured by Gross Domestic Product (GDP) per capita with the object of research of the European Union, USA, and Japan during the research period 1999-2019. Research conducted by Golpe *et al.*, *(*2023), he was found that monetary policy with indicators measuring inflation and interest rates was able to significantly increase economic development in terms of GDP in the European Union region. Research conducted by Al khatib (2023) found that not only monetary policy but also financial development variables significantly affect the economy as measured by GDP in Syria during the period 1980-2018, with the analytical techniques Nonlinear Autoregressive Distributed Lag (NARDL) model. Other researchers, such as Kumar and Jie (2023), have empirically tested that the effect of international financial stability can be a control variable between monetary policy on poverty reduction and improvement of human resource quality (GINI Index) in developing countries during the period 2004-2018 with Fixed Effect Method (FEM) research methods. In addition, empirical research by Fu *et al.*, (2023) has observed that monetary policy with interest rate proxies is also able to significantly affect renewable energy consumption in Brazil, Russia, India, China, and South Africa (BRICS) countries during the period 1990-2019, with the Method of Moment Quantile Regression (MMQR) analysis technique. Research conducted by Arintoko and Kadarwati (2022) found that monetary policy with inflation proxy and state exchange rate stability can significantly affect economic conditions in Indonesia, both short and long term, during the period 2001-2020, with the VECM analysis technique. Chugunov *et al.* (2021) study that fiscal policy, monetary policy as represented by proxy board money, and interest rates have significant impacts on economic development. More investigations, for instance, were done by Sun *et al.* (2022) on the period of 2000 to 2018 on G7 countries using the Stochastic Impact of Regression on Population, Affluence, and Technology (STIRPAT) analysis technique, did revealed that the expansionary type of monetary policy had a negative response to investments in renewable energy generation in G7 countries. Research by Zhang *et al.*, (2022) confirms that climate technology and financial stability contributed to human development and economic growth in developed countries in the period 2000-2019 using Autoregressive Distributed Lag (ARDL) techniques. Rahman *et al.*, (2019) found that in Bangladesh from 1997 to 2017 year there were considerable changes in economic growth as measured by GDP per capita due to inflation, broad money, and balance of payment. Research conducted by Cape *et al.*, (2019) found that variable interest rates and exchange rates could affect poverty in Indonesia during 1980-2017. Other researchers, such as Hashmi *et al.* (2022), found that interest rates can also affect renewable energy consumption in the US with ARDL analysis techniques. Research conducted by Choudhury (2018) found that the supply of money in a country can affect the productivity of goods /services, so it will increase national income. Other research conducted by Twinoburyo and Odhiambo (2018) found that monetary policy with interest rate proxies affects economic conditions in Tanzania more than money supply proxies during the period 1975-2013, with ARDL analysis techniques. In the research conducted by Srithilat and Sun (2017), the GDP per capita of developing nations from 1989 to 2016 was impacted both short- and long-term by exchange rate stability and monetary policy as a proxy for money demand, interest rates, and inflation with panel regression analysis techniques. In the research conducted by Batool *et al.*, (2020), this study examines the impact of financial development and institutional quality on environmental degradation in developed and developing countries from 1996 to 2016 using panel data analysis. Findings indicate that institutional quality, economic growth, FDI, and industrial growth increase CO_2 emissions, whereas financial development, urbanization, trade openness, and R&D expenditures reduce, and this study does not consider or specifically analyze the pillars of SDGs in G20 nations. Then the prioritization of SDGs for innovation and implementation, particularly concerning environmental sustainability, with climate change mitigation, but limited to exploring how monetary policies influence environmental sustainability outcomes. This study does not

Table 1: Definition of variables and measurements

Variable	Notation		Proxy	Data sources
Exogenous variables				
Monetary Stability	IR	1.	Interest rate	Worldbank
	BM	2.	Board money	IMF
	EX	3.	Exchange rate	
	BC	4.	Capital banks	
	MC	5.	Market capitalization	
Endogenous variables				
Pillars of Economic Development	GDP	1.	GDP per capita	Worldbank
	UR	2.	Unemployment rate	SDGindex
	TO	3.	Trade openness	
Pillars of Social Development	POV	1.	Poverty level	Worldbank
	GINI	2.	GINI Index	OECD SDGindex
Pillars of Environmental	REC	1.	Renewable energy	Worldbank
Development	CO2	2.	CO2 Emissions	SDGindex
Control variables				
Population	POP	Total of population		Worldbank
Inflation	CPI	Consumer Price Index		IMF

consider financial or monetary factors influencing SDG outcomes (Petrova, 2023).

MATERIALS AND METHODS

This research approach employs secondary data and a quantitative methodology. Panel data analysis is the method of analysis to explore the transmission mechanism of monetary policy towards SDGs on three main pillars (SDG Goals 1, 7, 8, 9, 10, 13) from a global perspective, with research objects in G20 countries. The European Union and 19 other nations make up the G20. Since the G20's member nations make up more than 60% of the world's population, 75% of global trade, and 80% of global GDP, we chose it for this research. The G20 members, which will be the subjects in this case study, include Argentina, France, Japan, China, Brazil, Indonesia, Russia, South Korea, Italy, Canada, Mexico, South Africa, Turkey, Saudi Arabia, Australia, India, Germany, the United States, England, and the European Union. Then this study uses data from 2010-2022 to determine the role of monetary stability of G20 countries, pre- and post-COVID-19 pandemic periods, in supporting sustainable development. The results of the achievement of the SDG index in G20 countries in 2022 are in the Moderately Increasing category, compared to 166 countries. This shows that G20 countries can complete the SDG goals at a moderate level, so research is needed on the role of monetary stability in the implementation of these SDG goals. Based on previous research literature, this study uses proxies of Board Money Supply (BMS), Interest Rate (IR), Exchange Rate (ER), Bank Capital (BC), and Market Capitalization (MC) to represent monetary stability. GDP, Unemployment Rate (UR), and Trade Openness (TO) are proxies for the pillars of a sustainable economy. The Poverty Rate (POV) and GINI index are proxies for the social pillar of sustainability. Emissions (CO2) and Renewable Energy Consumption (REC) as proxies for sustainable environmental pillars. With control variables, namely inflation and population growth rate (see Table 1). Based on earlier research, control variables were considered and used to eliminate potential bias in the model.

Data on variables were tested using panel methods to test the dynamic relationship between monetary stability and SDGs. Static panel models distinguish exogenous and endogenous variables. The Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM) are the three methods that can be used to estimate a panel data regression model. The Chow Test (proposed by econometrician Gregory Chow), the Hausman Test, and the Lagrange Multiplier (LM) Test were used to help choose the best panel data regression model estimate among the three models. After acquiring the best model, the next step is testing the classical assumptions, and the viability of the model (goodness of fit) is carried out (Gujarati, 2003). The procedures to arrive at the results in terms of the panel data regression order are

(1) identification of research variables and formulation of the model

(2) estimating the panel data using one of its components: the common effect, the given or fixed effect, and the random effect.

(3) the process of choosing the appropriate panel data regression models: Chow Test (Dollar Test), Hausman Test, and Lagrange Multiplier Test.

(4) performing the necessary analysis for the hypotheses formulated, Model Specification Test, and Classical Assumptions.

(5) detecting the model and hypothesis test (Basuki and Prawoto, 2016; Gujarati, 2003; Hsiao, 2014).

Model formation

The linear equation of the Panel model in this study can be formulated as follows:

Model (1) economic pillars:

SDG Goal 8 →

$$GDP_{ti} = \beta_0 - \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} + \beta_4 MC_{ti} + \beta_5 ER_{ti} - \beta_6 CPI_{ti} + \beta_7 POP_{ti} + \varepsilon_{ti}$$

$$UR_{ti} = \beta_0 + \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} + \beta_4 MC_{ti} + \beta_5 ER_{ti} + \beta_6 CPI_{ti} + \beta_7 POP_{ti} + \varepsilon_{ti}$$

SDG Goal 9 →

$$TO_{ti} = \beta_0 + \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} + \beta_4 MC_{ti} + \beta_5 ER_{ti} + \beta_6 CPI_{ti} + \beta_7 POP_{ti} + \varepsilon_{ti}$$

Model (2) social pillars:

SDG Goal 1 →

$$POV_{ti} = \beta_0 + \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} - \beta_4 MC_{ti} + \beta_5 ER_{ti} + \beta_6 CPI_{ti} - \beta_7 POP_{ti} + \varepsilon_{ti}$$

SDG Goal 10 →

$$GINI_{ti} = \beta_0 + \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} - \beta_4 MC_{ti} + \beta_5 ER_{ti} + \beta_6 CPI_{ti} + \beta_7 POP_{ti} + \varepsilon_{ti}$$

Model (3) environmental pillars:

SDG Goal 7 →

$$REC_{ti} = \beta_0 - \beta_1 IR_{ti} + \beta_2 BM_{ti} + \beta_3 BC_{ti} + \beta_4 MC_{ti} + \beta_5 ER_{ti} - \beta_6 CPI_{ti} + \beta_7 POP_{ti} + \varepsilon_{ti}$$

SDG Goal 13 →

$$CO2_{ti} = \beta_0 + \beta_1 IR_{ti} - \beta_2 BM_{ti} + \beta_3 BC_{ti} + \beta_4 MC_{ti} + \beta_5 ER_{ti} + \beta_6 CPI_{ti} - \beta_7 POP_{ti} + \varepsilon_{ti}$$

Information:

GDP = GDP per capita based on constant prices; UR = Unemployment Rate; TO = Trade Openness; POV = Poverty Rate; GINI = GINI Index; REC = Renewable Energy Consumption; CO2 = Carbon Emissions; IR = Interest Rate; BM = Board Money; BC = Bank Capital; MC = Market Capital; ER = Exchange Rate; CPI = Consumer Price Index; POP = Population; t = period, i = constant term; = coefficient; and = error term. $\beta_0 \beta_1, \beta_2, and\ \beta_3 \varepsilon$.

Panel data estimation model

The CE, FE, and RE models make up the estimation model with panel data. CE is a simple panel data model that combines cross-sectional and time series data. The CE model is oblivious to both the temporal aspect as well as the individual dimensions. Sometimes this model is called Ordinary Least Squares (OLS). The FE model is a data model that assumes differences between individuals can be accommodated by differences in interception. The FE model to estimate this panel data uses a technique with dummy variables as a differentiator between intercepts and individuals studied, so the FE model is called the Least Squares Dummy Variable (LSDV) (Basuki and Prawoto, 2016; Gujarati, 2003). This research, panel data combines information from different countries over multiple years, allowing us to see both differences between countries and changes over time. This is better than a cross-sectional analysis, which only looks at data from one point in time, or a time-series analysis, which focuses on trends in just one country. Panel data regression helps us understand how monetary stability affects SDGs by capturing economic patterns, policy impacts, and external shocks across G20 nations. Since these countries have different financial policies and economic structures, this method allows us to make more accurate comparisons. It also reduces bias by controlling for factors that remain constant within each country over time.

Panel data regression model selection

The Chow test is conducted to select either the Common Effect Model or the Fixed Effect Model. One runs the Chow test, which indicates that if the significance level is less than 0.05, then use FEM; and if the significance level is greater than 0.05, then the CE Model is used. Then the FE Model or RE Model is selected based on the Hausman Test at the significance level of 0.05, whereby if less than 0.05, then FEM is applied, if more than 0.05, then the RE Model is used (Gujarati, 2003; Hsiao, 2014).

Model estimation and hypothesis testing

The test of the hypothesis is for calculating how accurately the regression function describes real measured values from the goodness of fit. This may be calculated statistically by the F-test, R-squared, and T-test. F testing tests whether all independent

variables contained in the regression model influence the dependent variable. Through R-squared, the model's validity was tested by using a measure of distance for the model's explanation of the variation of the dependent variable. The t-test, in other words, tells one how much of the effect of one exogenous variable, either in part or as a whole, explains the endogenous variable (Basuki and Prawoto, 2016; Gujarati, 2003; Hsiao, 2014).

RESULTS AND DISCUSSION

Overview of SDGs

The Millennium Development Goals, often known as the MDGs, the United Nations Development Program (UNDP) The SDGs, which are made up of numerous additional and more universal goals that are interconnected with multi-dimensional objectives. Then, by integrating it into the SDG framework, the intersection of environmental, social, and economic sustainability is balanced. This is incorporated into the 17 goals and 169 targets, which in turn are translated into different, selected indicators for each of those goals. Hence, these 17 goals as the global framework that strives towards a better world; therefore, these are plans for people, and for the planet to achieve by 2030 (UNDP, 2022). Additionally, the 17 SDGs reflect both the pillars of the economy and society as well as the environment (Boar *et al.*, 2020). The first one is the economic pillar focuses on propelling the quality of economic growth with industrial creativity, inclusion, and sustainable employment, accomplishing the common vision of business opportunity, well-implemented infrastructure, clean energy, and global partnership delivery. The social pillar, in turn, concerns or is about the meeting of the fundamental human rights and justice conditions for well-being. Finally, within the environmental pillar, resource sustainability and a conducive environment for enhancing human life (Eisenmenger *et al.*, 2020; Swain and Yang-Wallentin, 2020; UNDP, 2022).

Development of SDGs

G20 countries were able to accomplish the SDGs index ranking with an overall score of 74.12, with the most successful being Germany in 2020 (Fig. 1) (United Nations, 2022). As stated in the annual report of the SDGs, this indicates G20 countries are progressing towards economic sustainability and prosperity while ensuring social continuity, environmental quality, and inclusive development. According to the G20 countries, it is necessary to eradicate poverty and foster national economic development while also addressing several social demands, like education, health, equality, availability of employment, dealing with climate change, and improving the conservation of the ecosystem. Consequently, G20 members refer to the 17 objectives of the SDGs.

Descriptive statistics

Normally distribution of quantitative data in the context of descriptive statistical analysis allows us to determine the minimum, maximum, mean, and standard deviation of some common values

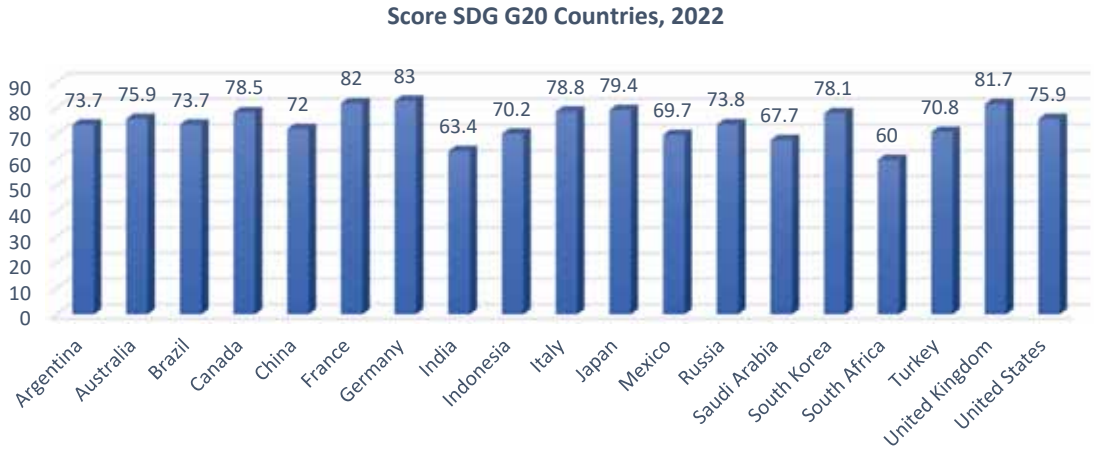

Fig. 1: Score SDGs of G20 countries in 2022

Table 2: Descriptive statistics

Variables	Mean	Median	Standard Deviation	Minimum	Maximum	Count
GDP per capita	26.662	24.176	18.811	1.351	76.399	260
Unemployment	116.816	34.695	185.556	11.040	781.831	260
Trade Openness	56	55	20	22	106	260
Poverty level	3	0.15	6	0.01	21	260
GINI	0.36	0.35	0.06	0.18	0.54	260
Emission carbon	1.437.026	503.214	2.254.435	154.536	10.944	260
Renewable energy	14	11	11	0.01	50	260
Board Money	89	74	57	6	286	260
Interest Rate	4	3	8	(13)	42	260
Bank capital	8	8	3	4	15	260
Market capitalization	75	62	57	6	331	260
Exchange Rate	697	4	2.760	1	14.850	260
Population	246.400	81.776	387.224	22.031	1.417.173	260
Inflation	4	3	5	(2)	72	260

(Ferdinand, 2014). In this section, variables in this study are summarized into tables with descriptive statistical data prepared in Table 2. According to the descriptive statistics results, there were 20 annual data observations. The mean for provisional GDP per capita is 26.66, for unemployment is 116.81; for trade openness is 56, with a poverty level of 3; and the GINI index is 0.36. The renewable energy average is 14, and the mean of the climate variable is 1.437. The mean value of the dependent variable, its board money, is equal to 89. The mean value of the interest rate is equal to 4; the bank capital to 8; the market capitalization to 75; and the mean value of the exchange rate is 697. As for the macroeconomic variables average for inflation is equal to 4, and the mean for the population is 246,4. G20, which is a group of twenty, comprises nineteen countries plus the European Union. The specific reason why this research focuses on the G20 is because of its members, who account for more than ten percent of the population, seventy-five percent of world trade, and eighty percent of the world. The objects of research conducted on G20 members consist of Argentina, France, Japan, China, Brazil, Indonesia, Russia, South Korea, Italy, Canada, Mexico, South Africa, Turkey, Saudi Arabia, Australia, India, Germany, the United States, England, and the European Union.

Classical assumption test

The regression estimation is appropriate for analysis from classical assumption tests on the exogenous variables that are not singular. In addition, the regression has a normal distribution, and no multicollinearity is detected. Regarding the autocorrelation test, the Durbin-Watson test showed that one cannot conclude anything about the autocorrelation coefficient, but this was different from the LM test of Breusch-Godfrey; it confirmed that there is no evidence of autocorrelation in the data.

Robustness checks

About robustness checks, this study includes two further variables, inflation and population, that are associated with the macro economy of countries from the G20 category. To make sure the estimation remains stable, the robustness test is performed in this case study. Furthermore, in light of the empirical results from the regression equation, the independent variables found include GDP per capita, unemployment rate, trade openness for the economic pillar, poverty level, and GINI index for the social pillar, and carbon emissions and renewable energy for the environmental pillar. Therefore, the regression results concerning the case of this research prove that all models are robust. On the contrary, the interpretation of the research empirical findings has the strength of the estimation (see Table 3).

Effect of monetary stability on the economic pillar of SDGs

The data presented in Table 4 shows that monetary stability affects the economic pillar of SDGs in G20 countries, and unemployment and GDP per capita are

Table 3: Regression analysis summary and main hypothesis compatibility

Hypothesis	Relationship Tested		Regression Result	Decisions
H.1.	Monetary Stability	GDP per capita	Significant	Supported
H.2.	Monetary Stability	Unemployment	Significant	Supported
H.3.	Monetary Stability	Trade openness	Significant	Supported
H.4.	Monetary Stability	Poverty	Significant	Supported
H.5.	Monetary Stability	GINI	Significant	Supported
H.6.	Monetary Stability	Emission carbon	Significant	Supported
H.7.	Monetary Stability	Renewable energy	Significant	Supported

Table 4: Effect of monetary stability role on the economic pillar of SDGs

Dependent Variables	Economic Pillar					
	(1) GDP per Capita		(2) Unemployment		(3) Trade Openness	
Independent Variables	β	Sig.	β	Sig.	β	Sig.
Board Money	0.0030	0.000***	0.0009	0.000***	-0.0581	0.023**
Interest Rate	-0.0133	0.017**	-0.0010	0.242	-0.3679	0.025**
Exchange Rate	0.0017	0.001***	3.9205	0.000***	0.0012	0.417
Bank capital	-0.0244	0.115	-0.0106	0.000***	-1.0733	0.018**
Market capitalization	-0.0011	0.129	-0.0002	0.031**	-0.0221	0.313
Constant	15.302	0.000	0.7554	0.000	110.078	0.000
R-Squared		0.554		0.992		0.128
Adj. R-Squared		0.539		0.992		0.100
Prop. > F		0.000		0.000		0.000

Notes: ***, **, * is the coefficients' significance threshold beginning at 1%, 5%, and 10%.

among the variables' components. According to the findings of the research, it was observed that all the contributory variables, which included board money, interest rate, exchange rate, bank capital, and market capitalization, have a significant influence on realizing the attainment of SDGS regarding the economic activities of the nation. While based on the statistical results, partially (sig-value), three variables from the Economic Pillar show different results. The GDP per capita variable is influenced by broad money, interest rate, and exchange rate in G20 countries; this result is in line with research (Arintoko and Kadarwati, 2022; Siklos, 2023). Then, it seems that a rise in the money supply tends to lower the cost of borrowing money, which can lead to higher consumption and lending rates, potentially boosting GDP in the short run (Afonso *et al.*, 2016). Next, one strategy for regulating inflation and economic growth is an interest rate policy. By changing the interest rate, they can control the money supply and therefore have an impact on the level of inflation, and in consequence, the level of economic growth. Additionally, the exchange rate might boost economic growth and reduce output volatility in emerging market economies. The growth of local currency bond markets may also be impacted by increased exchange rate flexibility and foreign investment in these markets (Hidayat *et al.*, 2019). The unemployment variable is influenced by broad money, exchange rate, bank capital, and market capitalization in G20 countries. Then it can be explained that it affects the board money in an economy and can lead to changes in interest rates, exchange rates, and the availability of credit, all of which can impact employment levels. The value of a nation's currency for other currencies is largely determined by the exchange rate (Hidayat *et al.*, 2019). A strong Yen is not good for Japanese exports, although it benefits the Japanese consumer, which can present issues on a global scale through increased unemployment in exporting countries. Bank capital is a critical factor in determining the level of credit available in the economy. Higher bank capital can lead to increased lending and lower unemployment, while lower bank capital can lead to reduced lending and higher unemployment (Ongena *et al.*, 2018). Then, a larger market capitalization can indicate a more developed and liquid financial system, which can lead to lower unemployment as it provides

more opportunities for investment and job creation (Soedarmono *et al.*, 2013). While trade openness is influenced by broad money, interest rates, and bank capital in G20 countries. Bank risk-taking behavior can be influenced by trade openness, and trade openness can influence bank risk-taking behavior is found to be significant (Neaime and Gaysset, 2018). Open economies are likely to react less to inflation changes but more to real exchange rate changes. This is because when formulating monetary policy, fluctuations in the actual exchange rate may be given more weight than fluctuations in inflation in open economies. Then, it is also confirmed that the degree of trade openness positively influences the growth of financial development (Ghazi, 2021). However, some researchers argue that strict monetary policies, like high interest rates to control inflation, can slow down economic growth and increase unemployment. Others suggest that excessive monetary easing can cause inflation and reduce the real value of wages, negatively affecting economic stability. These differing views highlight the complexity of balancing monetary policies to support both growth and stability in G20 countries. Monetary stability can be a solution and was crucial in supporting economic activity and ensuring price stability, with central banks cutting policy rates and committing to purchase large amounts of government and private assets to keep financial markets stable (Al khatib, 2023). Central banks have also taken measures to maintain adequate liquidity and financial stability, including lowering counter-cyclical capital or other systemic risk buffers, encouraging the use of capital and liquidity buffers, and modifying financial regulations or guidelines (Cihak & Fund, 2014). The Organization for Economic Cooperation and Development (OECD) Economic Outlook notes that the global economy proved resilient in 2023, especially in G20 countries, but there are signs that growth is easing as tight monetary policy takes hold. The outlook for global growth is forecasted to be 2.9% in 2024, improving slightly to 3.0% in 2025. The OECD has emphasized the importance of government spending focusing on monetary stability in areas that promote economic growth (OECD, 2023). Additionally, the impact of monetary stability on GDP and unemployment varies across countries due to differences in economic structures, labor markets, and policy effectiveness. Some G20 nations with strong financial systems may benefit more from stable monetary policies, while others with weaker institutions may struggle to achieve the same positive outcomes.

Model (1) economic pillars:

SDG Goal 8 →

$$GDP_{ti}=15.302_{0}-0.0133_{1}IR_{ti}+0.0030_{2}BM_{ti}-$$
$$0.0244_{3}BC_{ti}-0.0011_{4}MC_{ti}+0.0017_{5}ER_{ti}+\varepsilon_{ti}$$

$$UR_{ti}=0.7554_{0}-0.0010_{1}IR_{ti}+0.0009_{2}BM_{ti}-($$
$$0.0106_{3}BC_{ti}-0.0002_{4}MC_{ti}+3.9025_{5}ER_{ti}+\varepsilon_{ti}$$

SDG Goal 9 →

$$TO_{ti}=110.078_{0}-0.3679_{1}IR_{ti}-0.0581_{2}BM_{ti}-$$
$$1.0733_{3}BC_{ti}-0.0221_{4}MC_{ti}+0.0012_{5}ER_{ti}+\varepsilon_{ti}$$

Effect of monetary stability on the social pillar of SDGs

As to the social pillars, Table 5 examines the impact that Monetary Stability has on the social pillars of SDGs in the Q20 countries. From these empirical results simultaneously r-square, the aggregate social pillar outcomes in the G20 countries about monetary policy have been explained by poverty level and GINI variables. The findings also indicate partially (sig-value) that the variables from the social Pillar, poverty level, and GINI show different results. Poverty level is influenced by broad money, exchange rate, and market capitalization in G20 countries. Exchange rates can have both positive and negative effects on poverty levels. A stable exchange rate can promote trade and investment, which can lead to poverty reduction (Arintoko and Kadarwati, 2022; Wong *et al.*, 2023). Also, market capitalization can have both positive and negative effects on poverty levels. A well-developed financial sector can provide access to credit and financial services, which can help the poor to invest in productive activities and improve their economic well-being. However, monetary instability can have negative impacts on the poor, such as inflation, which erodes the real value of their incomes and assets more than those of the non-poor. Therefore, maintaining macroeconomic stability is critical for poverty reduction (Ongena *et al.*, 2018). Then, GINI is influenced by interest rates and market capitalization in G20 countries. Income inequality can be impacted by lower interest rates in both good and negative ways. Lower interest rates can lead to a shift towards riskier assets, which can benefit the wealthy

Table 5: Effect of monetary stability role on the social pillar of SDGs

Dependent Variables	Social Pillar			
	1) Poverty Level		2) GINI Level	
Independent Variables	β	Sig.	β	Sig.
Board Money	-0.0208	0.002***	-0.0001	0.155
Interest Rate	-0.0530	0.234	-0.0012	0.008**
Exchange Rate	0.0007	0.088*	-2.2806	0.606
Bank capital	-0.2007	0.103	-0.0017	0.191
Market capitalization	-0.0382	0.000***	-0.0012	0.064*
Constant	*16.5667*	*0.030*	*0.4368*	*0.000*
R-Squared		*0.284*		*0.087*
Adj. R-Squared		*0.261*		*0.058*
Prop. > F		*0.000*		*0.003*

Notes: ***, **, * is the coefficients' significance threshold begin at 1%, 5%, and 10%

who have better access to these markets (Wong *et al.*, 2023). The Gini coefficient may increase with a higher stock market capitalization ratio, signifying greater income inequality. This is because the wealthy tend to hold a larger share of their assets in financial markets, such as stocks, which can lead to a greater concentration of wealth among the top-income earners (Mathew, 2008). This result is in line with the research by Mathew (2008), Wolff (2021), and Wong *et al.*, (2023). However, critics argue that monetary stability alone is not enough to reduce inequality. Some studies suggest that financial inclusion and targeted fiscal policies are more effective in addressing social disparities. Additionally, rigid monetary policies might benefit financial markets but fail to address income inequality at the grassroots level. This suggests that while monetary stability is important, it should be complemented with policies that promote fair wealth distribution and social protection measures. Lastly, monetary stability can also contribute to realizing the social pillar as envisioned in the SDGs. In addition, monetary stability is also defined as an instrument of finance that guarantees the enhancement of the socioeconomic welfare of society (Sulaeman *et al.*, 2021). In the context of the social pillars of the SDGs, it is only the G20 countries that have reported monetary stability as a crucial component in the achievement of goals. Financial services, including investment and loan availability, which are prerequisites for economic activities supporting social welfare programs and education, healthcare, and infrastructure development, are guaranteed by a stable financial system (Neaime and Gaysset, 2018). In addition, monetary stability exercises control over the inflation rate, which is crucial for maintaining price stability and fostering long-term economic growth, both of which raise living standards and lower poverty over time (Wong *et al.*, 2023). Furthermore, the impact of monetary stability on poverty reduction differs among G20 countries. Advanced economies with strong social safety nets may experience better outcomes, while developing nations may require additional policies to maximize the benefits of monetary stability for poverty alleviation.

Model (2) social pillars:

SDG Goal 1 →

$$POV_{ti} = 16.5667_0 - 0.0530_1 IR_{ti} - 0.0208_2 BM_{ti} - 0.2007_3 BC_{ti} - 0.0382_4 MC_{ti} + 0.0007_5 ER_{ti} + \varepsilon_{ti}$$

SDG Goal 10 →

$$GINI_{ti} = 0.4368_0 - 0.0012_1 IR_{ti} - 0.0001_2 BM_{ti} - 0.0017_3 BC_{ti} - 0.0012_4 MC_{ti} - 2.2806_5 ER_{ti} + \varepsilon_{ti}$$

Effect of monetary stability on the environmental pillars of SDGs

As far as the environmental pillars are concerned, Table 6 describes the findings on a cross-country analysis of the relationship between the variable Monetary Stability and the environmental pillars of SDG in G20 countries. Where Monetary Stability affects the environmental pillars of SDGs in G20 countries simultaneously, R-squared, with dependent variable components being the emission of carbon and renewable energy. The findings also indicate that, partially based on the sig-value, the variables from the environment pillars conclude that the

Table 6: Effect of monetary stability role on the environmental pillars of SDGs

Dependent Variables	Environment Pillar			
	1) Emission Carbon		2) Renewable Energy	
Independent Variables	β	Sig.	β	Sig.
Board Money	0.0011	0.068*	-0.0384	0.000***
Interest Rate	-0.0202	0.000***	0.7143	0.000***
Exchange Rate	0.0001	0.000***	-0.0017	0.001**
Bank capital	0.0259	0.017**	1.1910	0.000***
Market capitalization	0.0025	0.000***	-0.0058	0.458
Constant	*3.2425*	*0.000*	*34.7399*	*0.000*
R-Squared		*0.792*		*0.594*
Adj. R-Squared		*0.785*		*0.583*
Prop. > F		*0.000*		*0.000*

Notes: ***, **, * is significance level of coefficients started from 1%, 5 %, 10%

results of board money, interest rate, exchange rate, and bank capitalization affect the emission of carbon and renewable energy in G20 countries. Then it can be explained that board money prioritizes sustainability and environmental responsibility and is more likely to implement measures to reduce carbon emissions. And more likely to implement measures to increase renewable energy production and consumption (D'Orazio and Popoyan, 2023). Lower interest rates may incentivize investments in carbon-intensive industries, leading to higher emissions. Conversely, higher interest rates could encourage investments in cleaner technologies and practices, reducing carbon emissions, and could discourage investments in renewable energy, making them less competitive compared to fossil fuels (Murshed *et al.*, 2023). Exchange rate fluctuations can affect the competitiveness of renewable energy projects in G20 countries. A weaker currency may make exports more attractive, potentially increasing the production and consumption of renewable energy. So, a stronger currency could make imports more affordable, influencing consumption patterns and emissions (ESMA, 2021). The capital held by banks can influence lending practices and investment decisions. Banks with stringent environmental criteria may prioritize funding projects that align with sustainability goals, leading to lower carbon emissions and renewable energy (Hashmi *et al.*, 2022). The market capitalization of companies reflects their value in the stock market. Companies with higher market capitalization often have greater resources to invest in sustainable practices and technologies, which can drive emission reduction efforts and investments in renewable energy (Murshed *et al.*, 2023; Zhang *et al.*, 2022). However, others suggest that monetary policies focused on short-term economic growth may lead to increased carbon emissions and environmental degradation, as industries prioritize profit over sustainability. The relationship between monetary stability and renewable energy usage is also complex. While lower interest rates can encourage green investments, they may also lead to increased industrial activities that contribute to higher emissions. This debate shows the need for integrating environmental policies into monetary frameworks to ensure that economic stability does not come at the cost of environmental sustainability. The existence of the G20 enhances the SDGs' economic and environmental pillars. Global financial stability is seriously threatened by climate change, and the G20 communities recognized that an urgent issue needs to be addressed. For instance, the G20's Green Finance initiative is designed to facilitate the development of green-raised capital in sustainable outlets. Therefore, the G20 has stressed the importance of macro-monetary and financial stability to strengthen downside volatility and the potential for long-term budget management. This stability is necessary for investment, innovation, and growth, which are all vital for the execution of the SDGs (Espinosa and Koh, 2024; G20, 2023; Teske, 2023). Additionally, the effect of monetary stability on renewable energy adoption differs across G20 nations due to variations in energy policies, availability of resources, and government incentives. Some countries, like Germany, have strong financial and policy support for renewable energy, leading to increased green investments.

Model (3) environmental pillars:

SDG Goal 7 →

$$REC_{ti} = 3.2425_0 - 0.0202_1 IR_{ti} + 0.0011_2 BM_{ti} + 0.0259_3 BC_{ti} + 0.0025_4 MC_{ti} + 0.0001_5 ER_{ti} + \varepsilon_{ti}$$

SDG Goal 13 →

$$CO2_{ti} = 34.7399_0 + 0.7143_1 IR_{ti} - 0.0384_2 BM_{ti} + 1.1910_3 BC_{ti} - 0.0058_4 MC_{ti} - 0.0017_5 ER_{ti} + \varepsilon_{ti}$$

CONCLUSION

The research here aims to investigate how the economic, social, and environmental pillars of sustainable development interact with monetary policy and exchange rates. It calls for a focus on the need to enhance economic sustainability, social welfare, the environment, and development inclusively. The panel regression model finds board money, exchange rate, and bank capital as a sub-monetary stability component to be productive in the Socio-Economic Development Indicators satisfaction SDG outcomes relating to three critical components of economic growth (GDP per capita), unemployment, trade openness, poverty, GINI index, renewable energy collectivization, and carbon dioxide emission. In light of this, this research supports the SDGs and the monetary policy transmission mechanism towards sustainable development in G20 countries and argues that G20 countries have pursued development in a manner consistent with the SDGs. These findings bring a perspective on sustainable development about monetary policy that is likely to address the pillars of sustainable development goals that are economic, social, and environmental. In particular, the G20 has launched some initiatives, such as the Climate Sustainability and Green Finance Study Group, that work towards the betterment of the economy. This focus aims at improving the financial system's capability to finance critical climate innovations, which are necessary to attain the SDGs. However, these initiatives are not sufficient to reach the SDGs in the case of the G20 countries. The SDGs remain in sight, but the strengths and weaknesses of each participating country are responsible for the discrepancy in the pace of Canada and the rest of the G20 nations. The G20 itself also struggles with many aspects, like the SDGs, for example, climatic challenges, that demand joint efforts and cooperation between its members. Limitations of the research include the reliance on panel data, limitations in the panel data analysis techniques used, and the scope of the research focusing on G20 countries. Recommendations based on the findings suggest the need for continued efforts by G20 countries to address poverty, enhance economic growth, promote sustainable development, and align policies with the SDGs. First, central banks should adopt flexible monetary policies that support economic expansion while keeping inflation under control. Lowering interest rates during economic downturns can encourage investment and job creation, while tightening policies when inflation rises can maintain price stability. Additionally, exchange rate stability should be a priority to promote trade and attract foreign investment, helping countries achieve their SDG economic goals without financial disruptions. Second, to enhance social and environmental sustainability, G20 policymakers should integrate green finance strategies into their monetary frameworks. Governments can provide low-interest loans and incentives for renewable energy projects, making it easier for businesses to transition to clean energy. The research emphasizes how crucial it is to track and assess how monetary stability and policy affect sustainable development objectives to ensure progress toward a more sustainable and inclusive future.

AUTHOR CONTRIBUTIONS

N. Prawoto conceptualized the study, drafted the initial manuscript, and contributed to the interpretation of the findings. A. T. Basuki contributed to the research design, assisted with manuscript development, and supervised data analysis. A. Munifatussaidah supported data collection, data interpretation, and manuscript revisions. I.Q. Ayun did an additional literature review, supervised data analysis, and approved the final manuscript. All authors reviewed and approved the final version.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

ARDL	Autoregressive Distributed Lag
ASEAN	Association of Southeast Asian Nations
BC	Bank Capital
BMS	Board Money Supply
BRICS	Brazil, Russia, India, China, South Africa
CEM	Common Effect Model
CPI	Consumer Price Index
ER	Exchange Rate
FEM	Fixed Effect Method
G20	The Group of Twenty
GDP	Gross Domestic Product
IMF	International Monetary Fund
IR	Interest Rate
LSDV	Least Squares Dummy Variable
MC	Market Capitalization
MMQR	Method of Moment Quantile Regression
NARDL	Nonlinear Autoregressive Distributed Lag
OECD	The Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
POV	Poverty Rate
REC	Renewable Energy Consumption
REM	Random Effect Model
SDGs	Sustainable Development Goals
SMEs	Small And Medium Enterprises
TO	Trade Openness
UNDP	United Nations Development Program
UR	Unemployment Rate

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ORIGINAL RESEARCH PAPER

Enhancing informal settlements through urban design, planning, and infill development

M. Razmaramina[1], M. Nazarabadian[1], S. A. Poorsarvghad[1], A. A. Pilehvar[2,*]

[1]*Department of Urbanism, Faculty of Architecture and Urbanism, Ferdowsi University of Mashhad, Mashhad, Iran*

[2]*Department of Urban Engineering, Faculty of Art, University of Bojnord, Bojnord, Iran*

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ABSTRACT

BACKGROUND AND OBJECTIVES: The growth and development of informal settlements are among the main challenges facing urban development, particularly in metropolitan areas. The Noh-Darreh area, located along the southern highlands of Mashhad, is a prominent example of informal settlements in the southwestern part of the city. It has attracted the attention of both the public and urban development institutions. Neglecting the needs and potential of the Noh-Darreh area in the planning and implementation of development projects could degrade its urban fabric, turning it into a deteriorated and unstable settlement, predominantly inhabited by migrants with a minimal sense of belonging to their place of residence. This study aims to explain and analyze the urban planning and design factors that impact the quality of informal settlements and evaluate their effectiveness in the Noh-Darreh area of Mashhad. By adopting an infill development approach, the research seeks to propose a viable model for improving the quality of life and habitability in the Noh-Darreh area.

METHODS: This study is purpose-driven and utilizes a mixed-methods research approach, combining qualitative and quantitative methods. Data was collected using the meta-synthesis technique, which involved a systematic review of reliable scientific databases and gathering insights from urban designers, managers, and development professionals. The findings were assessed using the Delphi technique.

FINDINGS: Based on the assessments, the most influential indicators using a substantive approach are land use and functionality (0.166), building characteristics (0.114), and the permeability of the fabric (0.107). In terms of a procedural approach, the key indicators are urban governance (0.069), social capital (0.067), and the characteristics of development plans (0.042). Additionally, planning and design strategies centered around infill development have been proposed in both the planning and design dimensions to improve the quality of informal settlements in the Noh-Darreh area.

CONCLUSION: The study reveals that targeted urban planning and design can significantly improve the quality of informal settlements through effective infill development. By focusing on key areas such as strengthening public spaces, optimizing land use, enhancing accessibility, protecting physical structures, and preserving the natural environment, we can transform these areas. Also, fostering strong partnerships between the government and communities and promoting economic infrastructure can create better opportunities. This approach can revitalize the Noh-Darreh area, turning it into a thriving, sustainable community and securing a brighter future for its residents.

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*Corresponding Author:
Email: *pilevar@ub.ac.ir*
Phone: 09153859458
ORCID: 0000-0003-2125-1274

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INTRODUCTION

Current cities, particularly megacities, are experiencing a continuous increase in population size as they extend beyond their urban borders, a phenomenon known as urban sprawl. This presents significant challenges for cities today. Additionally, many megacities contain informal and dilapidated urban areas that date back to their early establishment, which have had adverse effects on the cities' development and infrastructure (AlHasawi *et al.*, 2024). Informal settlements have become vital for space production and access to affordable housing, particularly in developing countries (Kamalipour, 2023). Residential and transportation patterns in dense and mixed urban areas have been significantly influenced by demographic shifts, rising costs, and the risks associated with automobile use. The increasing housing costs in desirable urban locations have further contributed to these changes. Concurrently, support for dense neighborhoods and informal settlements has diminished due to negative perceptions associated with these areas. Concerns such as high population density, the potential for social unrest and violence, feelings of inaccessibility, and divisive class dynamics have cast a shadow on the future of cities. Additionally, growing worries about environmental degradation and climate change have intensified these fears and increased skepticism regarding the expansion of urban informal settlements (Holden, 2019). Informal settlements are widely defined as rapidly growing, unauthorized, and self-organizing urban neighborhoods. These settlements have typically been formed through the influx of rural-to-urban migration, providing affordable housing for over a billion people and creating basic neighborhood infrastructure in developing cities (Dovey *et al.*, 2020). This issue is even more critical in metropolitan areas, where factors such as uncontrolled migration, high living costs, the disparity between citizens' income and expenses, and the need to be close to urban centers with access to city amenities exacerbate the problem. The rapid growth of urbanization, rural-to-urban migration, particularly to large cities like Mashhad, and the need to provide urban services that align with the needs of the urban population have emphasized the necessity of utilizing the existing capacities of the city. Providing sustainable urban growth and development through a practical model rather than horizontal urban expansion is essential to achieve this goal. This can be accomplished through infill development and the conversion of heterogeneous buildings. Furthermore, the demands of modern urban life indicate that cities, as living spaces, are losing their appeal to many citizens who often reside in suburban areas while working or studying in urban centers (Nazarabadian *et al.*, 2024). The Noh-Darreh area of Mashhad, one of the most prominent informal settlements, has become a major concern for urban managers and officials. Uncontrolled migration and unsustainable, unmonitored development have gradually deteriorated Noh-Darreh, causing it to lose its original identity. However, the availability of land suitable for development presents an opportunity to rectify the development challenges in this area. Infill development is one of the most effective urban development strategies for improving informal settlements. It involves minimal intervention in the existing fabric of the area while promoting coordination and adaptability between the new developments and the existing structures. These qualities make infill development an ideal approach for interventions in informal settlements. By implementing planning and design solutions, we can take significant steps toward realizing infill development and enhancing the quality of life in this area. Infill development is the creative recycling of brownfields and underutilized land in cities and urban suburbs. Successful infill development includes new brownfield plots in urbanized areas, redevelopment of underutilized building sites, and rehabilitation of historic buildings for new uses (Amiri and Lukumwena, 2020). Among residential expansions, newer residential units are created in the form of additional buildings through adjustments and modifications to existing plots, or by dividing existing houses into multiple residential units, or by creating new residential plots through the division and rezoning of existing plots of land. Infill development refers to the development of vacant, abandoned, underutilized, or neglected lands within the built-up areas of existing communities, where infrastructure is already in place. This approach offers a solution to fill the gaps within established communities and plays a pivotal role in achieving community revitalization, conserving land, and providing an alternative to urban sprawl. Infill development leverages existing infrastructure, enhances walkability by fostering a

safe and appealing pedestrian-friendly environment, and creates new opportunities for mixed-use developments, thereby restoring the "sense of place" that has often been diminished in large-scale development projects (Aly and Attwa, 2013). From this perspective, the infill development approach, which establishes a logical interplay between the spatial allocation of future urban redevelopment and the capacities of existing infrastructure, requires further exploration. This approach facilitates the maximum reintegration of underutilized and inefficient areas into the urban development cycle through urban planning objectives and infrastructure investments, by evaluating service levels and identifying critical infrastructure zones (Baird, 2011). This form of development, which focuses on inner-city lands and redirects the direction of expansion from peripheral areas to internal urban lands, is referred to as infill development (Pourmousavi *et al.*, 2014). Urban design and planning, as an interdisciplinary field, can offer solutions to enhance the quality of informal settlements through infill development. However, there has yet to be a comprehensive research model that combines design and planning approaches based on infill development in informal settlements. This study aims to provide such a model along with proposed solutions tailored to each component in the Noh-Darreh area of Mashhad. Given the stated issue, this research has been conducted to address the following two key questions:

1. *What are the urban planning and design components and indicators aligned with the infill development approach for improving the quality of informal settlements in the case area of Noh-Darreh?*

2. *What planning and design solutions, based on the infill development approach, can enhance the quality of informal settlements in the Noh-Darreh area?*

Background of research

In light of the research topic, Table 1 includes some of the most prominent studies that have the closest relevance to this research. Based on the conducted studies, previous research has never deeply or comprehensively addressed the interconnections between the concepts of incremental development, informal settlements, and related approaches such as urban design and planning knowledge, and has lacked operational solutions in this regard. This research, in addition to providing a comprehensive categorization of the design and planning components and indicators for incremental development in the informal settlement of Noh-Darreh, Mashhad, also includes a prioritization of the research components based on surveys conducted with experts.

MATERIALS AND METHODS

Survey design and data collection

This research falls under the category of applied research, aimed at improving the quality of informal settlements through urban planning and design factors influencing infill development. The research process involved five key steps. In the first step, a systematic review of research from two reputable academic databases, Scopus and Google Scholar, was conducted using three primary keywords related to the study. In the second step, after categorizing the indicators and components into six systems with a design-oriented approach and three systems with a planning-oriented approach, the resulting model was tested for its effectiveness and scientific value using the Delphi technique. This was done by a group of experts familiar with the research topic, including urban designers and planners, city managers, urban development specialists, and university professors, in two stages. In the third step, after refining the research model to assess and determine the significance and impact of each component, the Analytic Hierarchy Process (AHP) method, along with the Expert Choice software, was used for pairwise comparisons of the research components, and the weight of each component was calculated. In the fifth step, solutions, operational goals, and policies were provided for each system. Fig. 1 illustrates the comprehensive structure of the research.

Systematic review

Data collection for this study was carried out using a systematic review method across two scientific databases, Scopus and Google Scholar, following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) framework as illustrated in Fig. 2. It should be noted that the studies from the systematic review were thoroughly examined using the Glynn checklist tool in the fourth step. The research was examined based on four main indicators: the statistical population, the data collection method (Clear description of data collection methods

Table 1: A review of the research background on a global and local scale

Reference	Research topic	Summary of research findings	Critiques and research gaps
		Local experiences	
(Nazarabadian *et al.,* 2024)	Explaining the Model of Promoting Infill Development by Urban Design in a Historical Context of Mashhad Metropolis	This research, through two key tools—urban design and policymaking—has developed a comprehensive and practical model to explain the factors influencing the realization of infill development in Mashhad's historical and central fabric. Therefore, by utilizing the proposed model and its implementation, which includes enhancing functional quality, aesthetic aspects (both subjective and objective), environmental improvements, and the advancement of the local community's situation, a significant step is taken toward executing infill development in Mashhad's historically significant urban fabric.	1-The study focuses specifically on Mashhad's historical fabric, which may limit the applicability of its model to other cities with different socio-cultural or urban contexts. 2-While the model emphasizes policy and design tools, it does not thoroughly address potential barriers like funding constraints, bureaucratic hurdles, or community resistance. 3-The role of local communities and stakeholders in co-designing interventions is underexplored, risking top-down solutions that may not align with residents' needs.
(Mohammadi-Hamidi *et al.,* 2022)	Urban infill development: a strategy for saving peri-urban areas in developing countries (the case study of Ardabil, Iran)	The research findings indicate that between 2000 and 2020, 967 hectares of peri-urban land were lost due to urban expansion. It also shows that 452 hectares will be lost by 2030. The evaluation of the city's internal capacity for infill development revealed that over 999 hectares of land within the city are suitable for supporting this strategy and providing the land needed for urban development. The comprehensive city plan, which applies to all cities in Iran, ultimately revealed that there is a lack of sufficient foresight regarding the amount of land available for future urban development, leading to land misuse and urban sprawl in Iranian cities.	1-While 999 ha is identified as suitable for infill, the paper doesn't clarify the selection criteria (e.g., ownership patterns, infrastructure readiness, or community needs). 2-The critique of Iran's comprehensive plans is valid, but the study doesn't propose actionable alternatives to overcome their shortcomings in practice. 3-The study quantifies land loss but doesn't deeply analyze the underlying drivers (e.g., weak land governance, speculative markets), enabling urban sprawl in Ardabil.
(Gharebaglou *et al.,* 2019)	Infill Architecture: An Interdisciplinary Approach to the Design of Historic Context; Case Study: Mashruteh Complex in the Historic Bazaar of Tabriz, Iran.	The results of this study indicate that infill development is an interdisciplinary approach to urban planning that takes into account the criteria for smart, sustainable development and new urbanism. This interdisciplinary perspective helps define infill development within a feedback model across the relevant fields.	1-Findings focus on a specific historic complex, raising questions about applicability to non-historic or less culturally significant areas. 2- While advocating an interdisciplinary approach, the study doesn't address practical barriers like regulatory constraints or stakeholder conflicts in historic preservation.
		Global experiences	
(Kamalipour, 2024)	Informal urban design: forms of informal settlement	This research provides an overview of the body of urban design knowledge and examines the topics of morphology and transformations of informal settlements regarding the dynamics of view and place identity. The results indicate that urban design, by considering the capacities of the area, can address the challenges of informal settlements.	1-The study overlooks the critical role of community participation and local knowledge in shaping informal settlement transformations. 2-While the study effectively analyzes morphology and identity, it fails to provide concrete design strategies or policy recommendations for improving informal settlements.
(Boanada-Fuchs *et al.,* 2024)	A Global Estimate of the Size and Location of Informal Settlements	This study aims to provide a more precise understanding of the geography of slums, informal settlements, and their growth patterns. The results indicate that the Sustainable Development Goals (ensuring access for all to adequate, safe, and affordable housing and basic services and improving slum neighborhoods) are targeted interventions in poor neighborhoods. Informal settlements are strongly linked to political and administrative boundaries.	1- The 30-city sample is skewed toward large cities and capital cities, neglecting smaller urban areas where slum dynamics may differ significantly.

Table 1: A review of the research background on a global and local scale

Reference	Research topic	Summary of research findings	Critiques and research gaps
(Kamalipour, 2023)	Shaping public space in informal settlements: A case study	This research addresses the challenge of understanding the shaping of public space in informal settlements, focusing on exploring spatial structures and the increasing transformations through a case study in Medellín (Colombia). It also presents a critical case study that has experienced both informal and formal transformations. The findings of this study can offer a better understanding of how public spaces are formed in informal settlements, while also suggesting related improvement strategies.	1- Methods rely heavily on observation and photography, omitting direct input from residents on public space formation.
(Kamalipour and Dovey, 2020)	Incremental production of urban space: A typology of informal design	This study examines informal settlements from both urban design and planning perspectives. A typology is proposed in the paper to understand the morphologies of informal housing. The findings indicate that development indicators, connectivity, substitution, division, annexation, and infill development are key factors for enhancing informal settlements.	1- The study primarily analyzes the morphology and physical design of informal settlements, while socio-economic factors (e.g., poverty, inequality, governance) are understudied. 2- While the typology of incremental changes is useful, the paper fails to propose actionable strategies for policymakers or urban designers.
(Admasu, 2015)	Urban land use dynamics, the nexus between land use pattern and its challenges: The case of Hawassa City, Southern Ethiopia	This study examines the relationship between land use patterns and their challenges in Hawassa City. It attempts to investigate the major factors influencing land use changes over time. The study also aims to discuss the primary structures governing urban land use in the area of interest. Additionally, urban development is discussed, and land use scenarios in Hawassa City are evaluated within a temporal context.	1-The study primarily analyzes physical and spatial changes in land use, while socio-economic drivers such as poverty, inequality, and community agency are understudied. 2-While the study identifies key challenges (e.g., informal land markets), it fails to propose actionable strategies for policymakers to improve land governance or reduce informality.

(questionnaires, interviews, etc.) and review of validity and reliability of data collection tools), the research structure, and the research results (Check that study results are directly related to the research questions and that research findings address inclusive development in informal settlements). Finally, 46 selected studies were analyzed, and the cases mentioned in the research background demonstrated the highest relevance to the current study.

According to the systematic review, the three main research keywords—urban design and planning, infill development, and informal settlements—were examined in a binary manner. As shown in Fig. 3, the number of studies related to the keywords “urban design and planning” and “informal settlements” has significantly increased from 1990 to 2024, particularly since 2016. Despite the growing focus on exploring the relationship between these two areas in recent years, the direct connection between urban design and planning indicators that affect the quality of informal settlements has been largely overlooked, with only a few aspects of this relationship being investigated.

The results of the binary search for the keywords “urban design and planning” and “infill development,” as shown in Fig. 4, indicate a growing interest in the relationship between these two concepts, particularly in recent years. A review of the articles gathered from the systematic review reveals that research has not yet thoroughly explored the urban design and planning factors that influence infill development.

In the third stage of the binary analysis of research keywords, we examined the results for the two keywords: “infill development” and “informal settlements.” As illustrated in Fig. 5, there is a limited number of studies that have explored the relationship between these two concepts. This finding highlights the need for a thorough examination of how infill development impacts informal settlements, a topic that will be addressed comprehensively in the

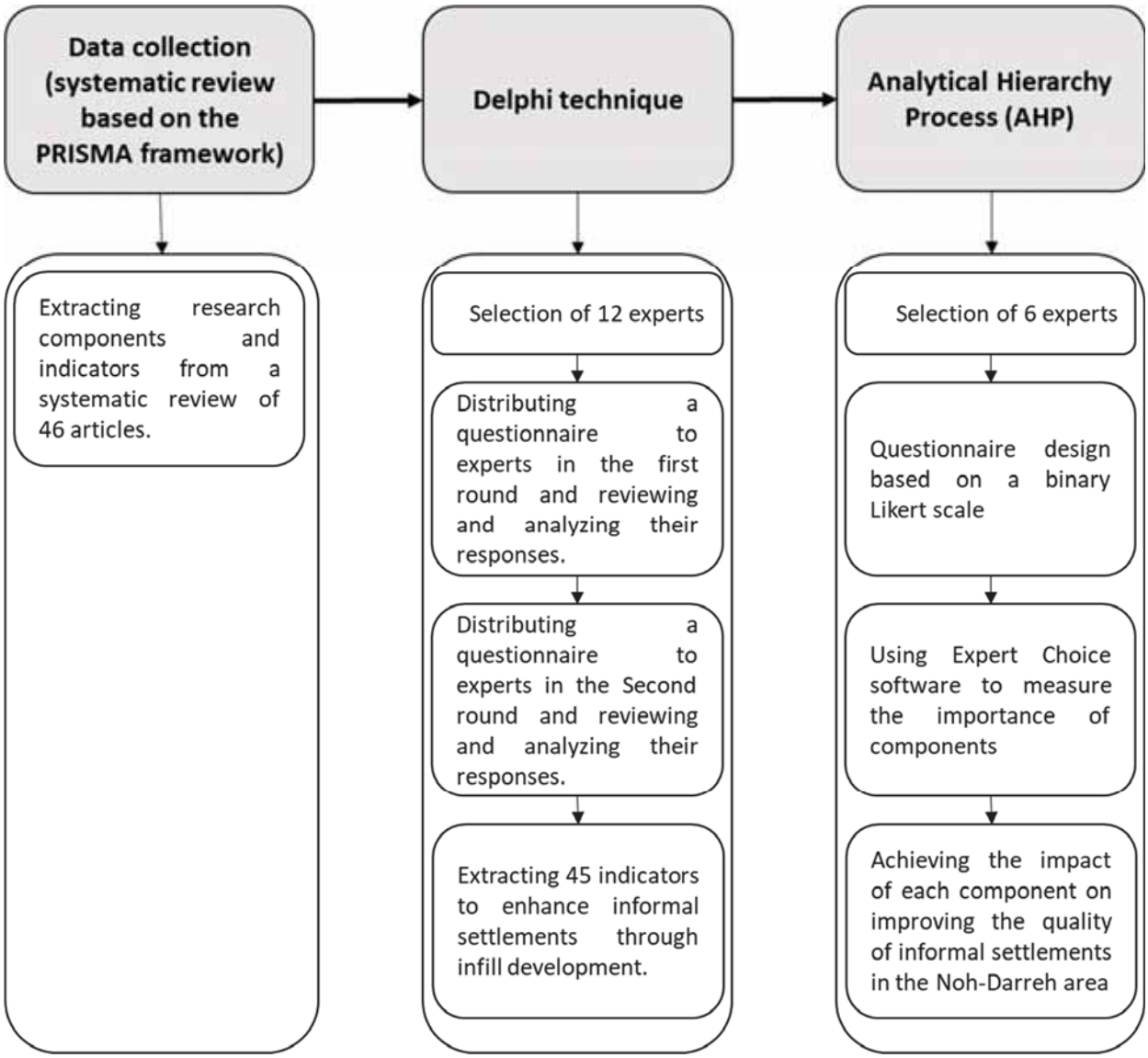

Fig. 1: Research structure

remainder of the study.

Based on the studies conducted, there is currently no comprehensive research that examines the relationship between urban design and planning, infill development, and informal settlements. Additionally, there have been no studies that provide solutions for improving the quality of informal settlements through infill development by leveraging urban planning and design solutions.

Developing the conceptual framework of the study and the Delphi technique

Following an in-depth investigation and analysis of the selected studies conducted based on the systematic review, the identified indicators were categorized based on various components, including systems of physical form, infrastructure and public spaces, movement and accessibility, land use, views and perspectives, environmental factors, as well

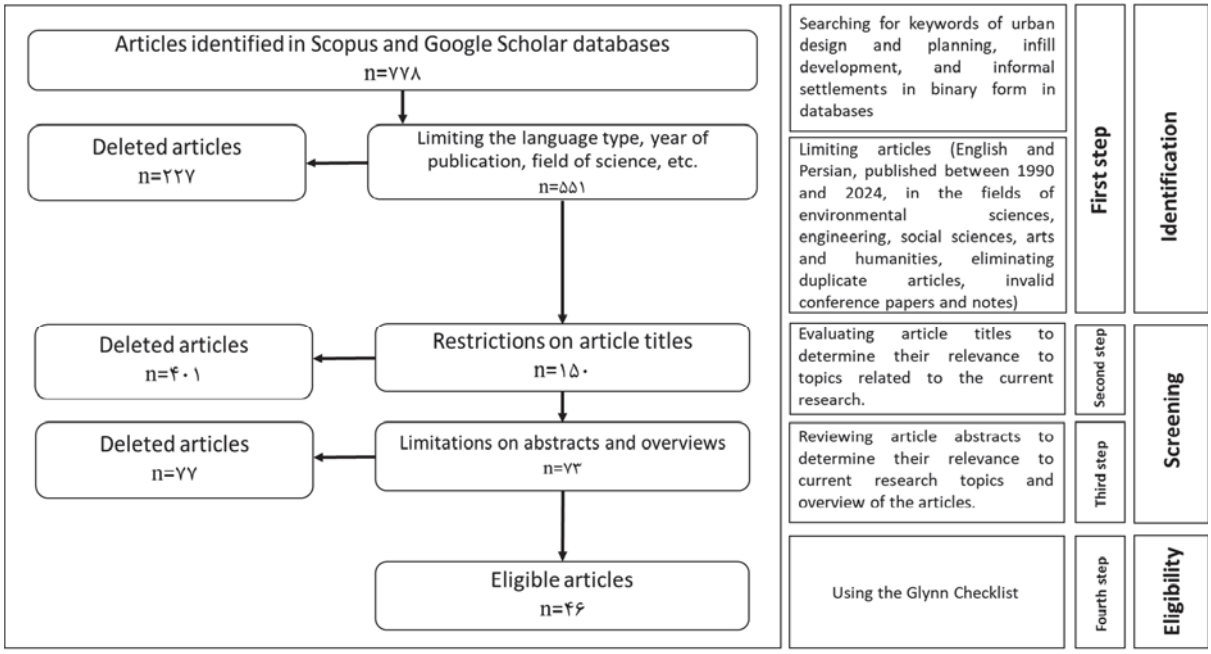

Fig. 2: Bibliographic search and systematic review process

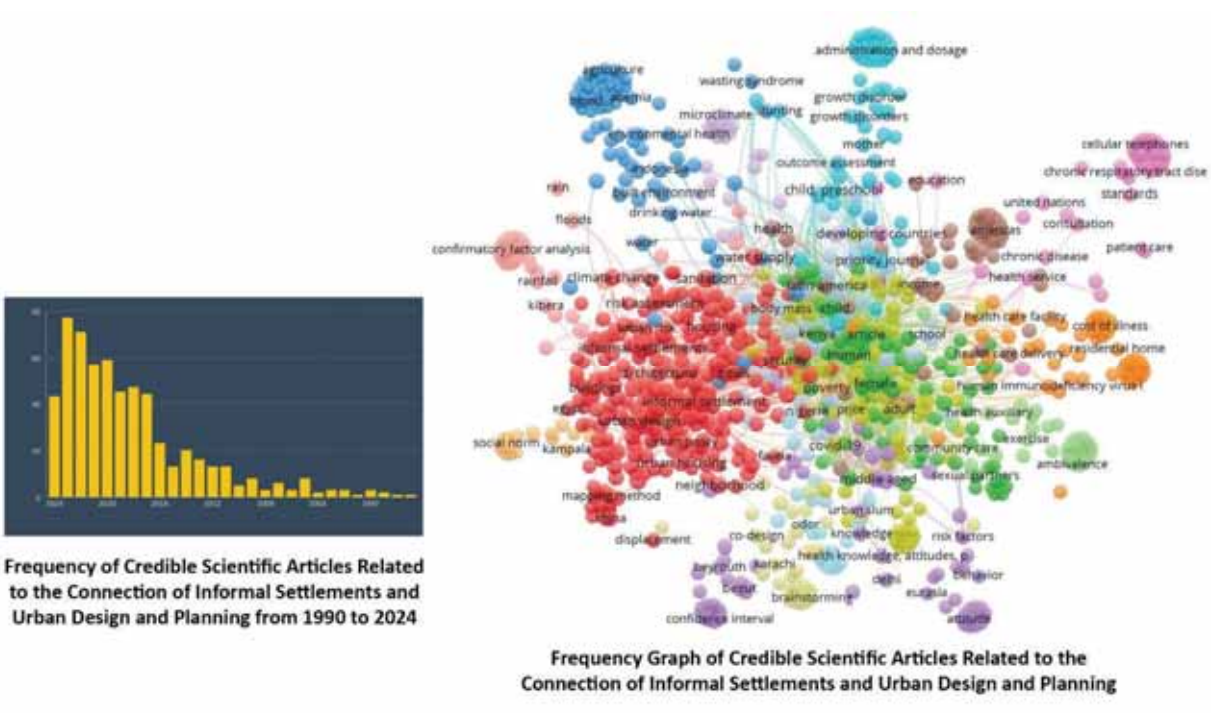

Fig. **3**: Relationship between the keywords of urban design and planning and informal settlements in previous studies

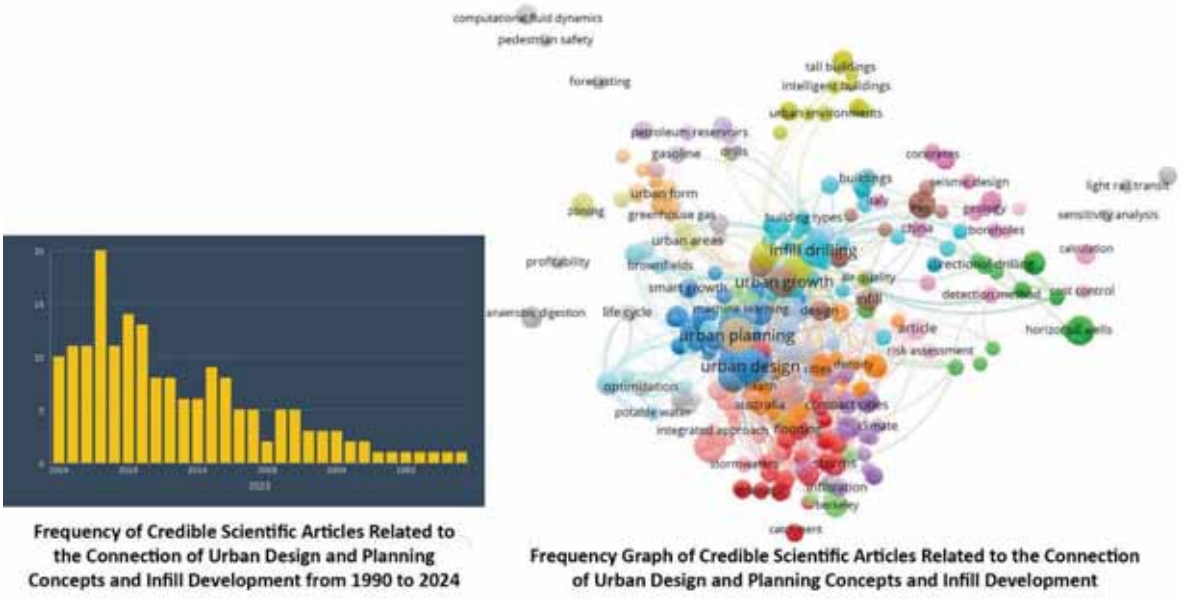

Fig. 4: Relationship between the keywords of urban design and planning and infill development in previous studies

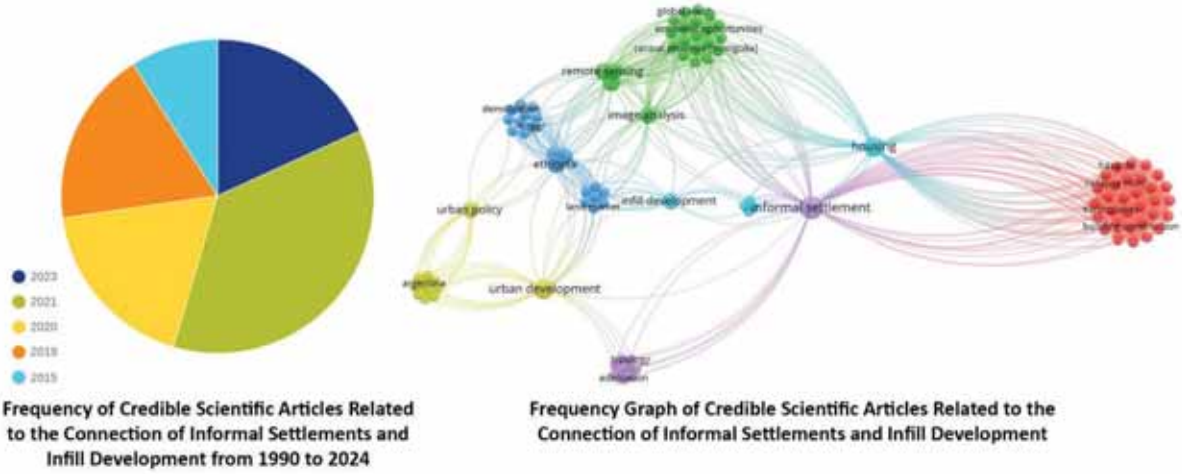

Fig. 5: Relationship between the keywords of informal settlements and infill development in previous studies

as institutional-management, socio-cultural, and economic systems, organized according to two approaches: design-oriented and planning-oriented. To ensure validity, the classification developed using the Delphi technique was monitored in two stages by a group of 12 experts. This group included six academic experts, four executive managers, and two local consultants. All participants held a master's degree or higher, specialized in infill development, and had either published scientific articles on the subject or possessed relevant executive experience. It is important to note that the selection of the expert sample was conducted using the snowball sampling method, continuing until theoretical saturation was achieved. Theoretical saturation in qualitative research means sampling continues until no new

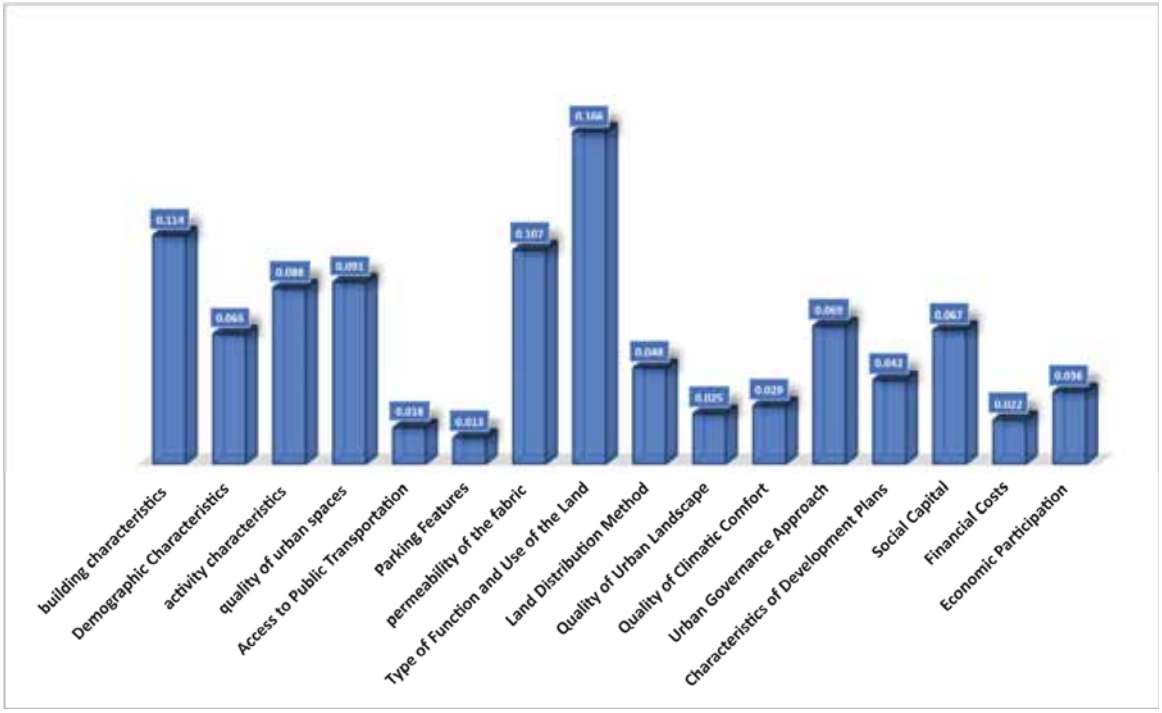

Fig. 6: Evaluation of Research Components in the Noh-Darreh Area of Mashhad Using Hierarchical Analysis Method

information or insights are gained (Pakgohar and Khalili, 2021). Table 2 provides a comprehensive classification of 45 indicators derived from 16 components across 9 systems, categorized according to the two design-oriented and planning-oriented approaches, which can be utilized for evaluating the enhancement of informal settlements through infill development.

Hierarchical analysis and evaluation, and measurement of the importance and impact of research components

To conduct a hierarchical analysis to measure the importance of 16 research components, a questionnaire was prepared, and a binary comparison of research components was made based on a 5-point Likert scale by six experts with a master's degree or higher who had a research background in the field of infill development. It should be noted that the process of selecting the statistical population continued until theoretical saturation of opinions was achieved. After the completion of the questionnaires by the experts, their results were entered into the Expert Choice software environment. Fig. 6 accurately displays the weight and impact of each component for improving the quality of informal settlements in the Noh-Darreh area.

RESULTS AND DISCUSSION

Infill development

The concept of infill development was first introduced in 1976 at the Habitat I Conference in Canada (Pourmousavi *et al.*, 2014). Three years later, in 1979, the National Association of Realtors in the United States officially defined the concept of infill development and applied it toward economic objectives (Hudnut, 2001). Infill development is the process of redeveloping and reusing vacant, underutilized, or abandoned parcels of land within existing urban areas that have already been developed (Enger, 1997). This type of development occurs at various scales, from individual plots to entire urban districts. Often considered the simplest form of endogenous development, infill development focuses on vacant and abandoned inner-city lands, intending to concentrate urban growth on these sites (Walters and Brown, 2012). The term "infill development" encompasses urban renewal, rehabilitation, and, in

Table 2: Research model of urban planning and design impacting infill development for the improvement of informal settlements

Approach	Systems	Components	Indicators	Reference
1. Design-oriented (Substantive Approach)	1. Physical Form	1. Building Features	1. Building Age	(Nazarabadian *et al.,* 2024)
			2. Building Quality	(Nazarabadian *et al.,* 2024; Kamalipour and Dovey, 2020; Dovey *et al.,* 2020; Tabibian and Ghani, 2016)
			3. Type of Building	(Nazarabadian *et al.,* 2024; Kamalipour and Dovey, 2020)
			4. Number of Floors of Buildings	(Holden, 2019; Aly and Attwa, 2013; Dovey *et al.,* 2020; Tabibian and Ghani, 2016)
			5. Diversity in the Physical Form of Buildings	(Nazarabadian *et al.,* 2024; Aly and Attwa, 2013)
	2. The Framework of Public Spaces	1. Demographic Characteristics	1. Population Density	(Admasu, 2015; Nazarabadian *et al.,* 2024; Carrilho and Trindade, 2022; Tabibian and Ghani, 2016)
			2. Population Decentralization from Informal Settlements	(Admasu, 2015; Dovey and King, 2011; Beardsley and Werthmann, 2008; Kamalipour and Dovey 2020; Dovey *et al.,* 2020; Boanada-Fuchs *et al.,* 2024)
		2. Activity Characteristics	1. Activity Diversity	(Nazarabadian *et al.,* 2024; Aly and Attwa, 2013)
			2.Vitality	(Aly and Attwa, 2013)
			3. The Arrangement of Hangouts and Behavioral Settlements	(Nazarabadian *et al.,* 2024; Dovey *et al.,* 2020)
			4. Activity Compatibility	(Aly and Attwa, 2013)
		3. Quality of Urban Spaces	1. Proper Separation of Public and Private Spaces	(Nazarabadian *et al.,* 2024; Kamalipour and Dovey, 2020; Kamalipour, 2023; Pourmousavi *et al.,* 2014)
			2.Sense of Place	(Aly and Attwa, 2013)
			3. Safety of Public Spaces	(Aly and Attwa, 2013; Boanada-Fuchs *et al.,* 2024)
	3. Movement and Accessibility	1. Access to Public Transportation	1. Distance to the Metro Station	(Nazarabadian *et al.,* 2024; Holden, 2019; Beardsley and Werthmann, 2008; Tabibian and Ghani, 2016)
			2. Distance to the Bus Station	(Nazarabadian *et al.,* 2024; Beardsley and Werthmann, 2008; Tabibian and Ghani, 2016)
		2. Parking Features	1. Presence of Shared Parking	(Tabibian and Ghani, 2016; Pourmousavi *et al.,* 2014)
			2. Parking Fees	(Pourmousavi *et al.,* 2014)
			3. Distance to the Public Parking	(Nazarabadian *et al.,* 2024; Holden, 2019)
		3. Permeability of the Fabric	1. Possibility of Pedestrian and Vehicle Access Within Urban Blocks	(Dovey and King, 2011; Aly and Attwa, 2013; Dovey *et al.,* 2020; Kamalipour, 2023; Pourmousavi *et al.,* 2014)
			2. Degree of Enclosure	(Nazarabadian *et al.,* 2024)
	4. Land Use	1. Type of Function and Use of the Land	1. Brown Fields	(Nazarabadian *et al.,* 2024; Tabibian and Ghani, 2016)
			2. Abandoned and Ruined Lands	(Kamalipour and Dovey, 2020; Tabibian and Ghani, 2016)
			3. Barren and Built-up Lands	(Nazarabadian *et al.,* 2024; Tabibian and Ghani, 2016)
			4. Multifunctional Land Uses	(Nazarabadian *et al.,* 2024; Aly and Attwa, 2013; Kamalipour, 2023)
			5. Urban Development and Reserve Lands	(Tabibian and Ghani, 2016)

Table 2: Research model of urban planning and design impacting infill development for the improvement of informal settlements

Approach	Systems	Components	Indicators	Reference
		2. Land Distribution Method	1. Equitable Land Distribution	(Nazarabadian *et al.,* 2024; Dovey and King, 2011)
			2. Construction of Social Housing	(Holden, 2019)
	5. View and Landscape	1. Quality of Urban Landscape	1. Lynch's Legibility Elements (Path, Edge, Node, District, and Landmark)	(Nazarabadian *et al.,* 2024; Dovey and King, 2011)
			2. Symbols	(Nazarabadian *et al.,* 2024; Dovey and King, 2011)
	6. Environmental	1. Quality of Climatic Comfort	1. Quality of Cleanliness and Level of Hygiene Maintenance in the Environment	(Admasu, 2015; Beardsley and Werthmann, 2008; Kamalipour and Dovey, 2020)
			2. Amount of Vegetation Cover and Green Spaces	(Admasu, 2015)
2. Planning (Procedural Approach)	7. Institutional-Managerial	1. Urban Governance Approach	1. Supply and Demand Management in Land Allocation	(Admasu, 2015; Holden, 2019; Dovey and King, 2011; Aly and Attwa, 2013)
			2. Land Allocation to People Through Official and Legal Institutions	(Admasu, 2015; Dovey and King, 2011; Carrilho and Trindade, 2022)
		2. Characteristics of Development Plans	1. Feasibility of Land Use Plans	(Admasu, 2015; Aly and Attwa, 2013)
			2. Revision of Local Development Plans	(Admasu, 2015; Holden, 2019)
			3. Comprehensive Land Information System Database	(Admasu, 2015)
	8. Social and Cultural	1. Social Capital	1. Local Community Participation	(Admasu, 2015; Aly and Attwa, 2013; Boanada-Fuchs *et al.,* 2024; Pourmousavi *et al.,* 2014)
			2. Level of Knowledge, Awareness, and Information of the Area's Residents	(Admasu, 2015; Aly and Attwa, 2013)
			3. Level of Attachment and Sense of Belonging of Residents to the Neighborhood	(Admasu, 2015; Nazarabadian *et al.,* 2024)
			4. Cultural-Social Events	(Nazarabadian *et al.,* 2024)
	9. Economic	1. Financial Costs	1. Land Value (Price)	(Nazarabadian *et al.,* 2024; Holden, 2019; Aly and Attwa, 2013)
			2. Construction Costs	(Nazarabadian *et al.,* 2024; Aly and Attwa, 2013)
		2. Economic Participation	1. Level of Private Sector Economic Participation	(Admasu, 2015; Nazarabadian *et al.,* 2024; Dovey and King, 2011; Beardsley and Werthmann, 2008; Carrilho and Trindade, 2022)
			2. Stabilization and Support of Local Businesses	(Pourmousavi *et al.,* 2014)

a sense, the repurposing of existing urban spaces. It involves the equitable distribution of buildings and urban amenities across all areas of the city while facilitating the potential for reconstruction and the reorganization of the city's physical fabric (Jaliz *et al.,* 2020). Successful infill development integrates new structures into the urban context, enhances the city's livability, and ensures that both current infrastructure and future developments are considered (EPA, 2004). In this framework, urban sprawl and horizontal

expansion contribute to land and environmental degradation. As a result, urban planning strategies should focus on directing the city's growth toward vacant land within urban areas, often referred to as 'Brown Fields' (Pourmousavi *et al.*, 2014). In many communities, there are significant areas of vacant land within urban boundaries that have been overlooked through the urbanization process for various reasons. In general, infill development refers to new development on vacant, abandoned, or designated land within already developed areas, where infrastructure is already in place (Aly and Attwa, 2013; Felt, 2007). In other words, the infill approach in developed areas is an effective strategy for sustainable urban development, fully aligning with the objectives and goals of modern urban planning (Eichhor *et al.*, 2021). This type of development can be carried out by developing and constructing vacant lands, reusing unused lands, or changing the lands and buildings used to accommodate new purposes (Ghodsi *et al.*, 2021). The demolition of existing structures, the construction of new buildings, or the comprehensive renovation of existing structures often alters their form and function. Development sites can be categorized as vacant lands, which often become dumping grounds posing health and safety risks; abandoned properties requiring maintenance or demolition costs; or brownfields, typically sites previously used for old industries, businesses, or warehouses (Aly and Attwa, 2013). A key sustainability goal is to limit urban land-use expansion, for which infill development is considered the primary strategy (Schiller *et al.*, 2021). Infill development, which involves the construction and utilization of vacant or underutilized lands, is a tactic within the framework of regional smart growth strategies (Khorrami *et al.*, 2021). While planners in recent years have recognized that higher density, more diverse environments, better signage, and improved accessibility to destinations can reduce automobile dependency (Beygi Heidarlou *et al.*, 2020), the effects of planning measures such as permitting specific developments, increasing density in particular locations, or enhancing vehicle mixes at specific activity centers have rarely been studied in depth (Merlin, 2018). Among the various forms of urban development, infill development is recognized as one of the most critical and effective strategies. It provides a practical approach to fostering stability within urban fabrics, enhancing the quality of informal settlements, preserving historical identities, creating distinct and coherent urban spaces, curbing urban sprawl, and meeting the needs of local communities and residents. From an aesthetic standpoint, its strategies include the restoration and adaptive reuse of historically significant buildings, the revitalization of deteriorated areas in compliance with modern construction standards, the moderation of residential density to prevent overcrowding, and the application of materials that align with the historical character of the area.

Informal settlement

Informal settlements represent one of the most common forms of urbanization worldwide, comprising nearly one-third of all urban structures. By the mid-21st century, it is anticipated that up to three billion people will inhabit these informal urban environments (Desa, 2019). Informal settlements are one of the most prominent forms of urban poverty, defined as areas that develop spontaneously or illegally within or on the outskirts of cities (especially large cities), without proper authorization, building permits, or formal urban planning. These settlements are typically inhabited by low-income groups and characterized by poor living conditions in terms of both quantity and quality. This phenomenon is commonly referred to by terms such as marginalization, spontaneous settlements, informal communities, and slum areas (Piran, 2003). These settlements face numerous challenges, including various forms of pollution, environmental issues, lack of access to clean drinking water, inadequate open spaces, overpopulation, insufficient services, poverty, insecurity, and unemployment. Given that these settlements develop overnight and informally, they lack basic standards and are highly vulnerable to both natural and man-made disasters (Zerbo *et al.*, 2020; E. West *et al.*, 2020; Khalil *et al.*, 2016; J. Van Welie, 2016). In the definitions provided by the United Nations, terms such as slums and shantytowns are used interchangeably with informal settlements. According to the United Nations definition, informal settlements refer to areas within cities that:

1) *Their residents do not have ownership rights to the properties.*

2) *They are faced with a shortage of basic services and urban infrastructure*.

3) *The housing constructed in these areas does*

not comply with standard regulations and building codes (UN-Habitat, 2015).

It is important to note that many residents of informal settlements did not migrate to land; rather, they have been pushed to their plots, either directly or indirectly, by government policies or clientelistic practices. Additionally, there are instances where settlements that are technically "formal" are perceived as "informal" by the public due to their characteristics (Pojani, 2019). However, we lack a consistent mapping method to accurately determine the location of informal settlements or how they expand (Samper *et al.*, 2020). Despite the relative decrease in the proportion of people living in informal settlements, the absolute number of urban residents living in impoverished neighborhoods continues to rise (Messerli *et al.*, 2019). The most important feature of urban planning and design for informal settlements is their ongoing transformation. Research on urban mapping and changes challenges the view of informality as unplanned or chaotic, arguing instead that these areas undergo predictable changes, densification, and evolution (Samper and Liao, 2023; Patel *et al.*, 2012). Informal settlements have created significant challenges in urban planning and design. Therefore, the importance and role of these two approaches in improving the quality of these settlements have become increasingly critical. By understanding the planning and design factors influencing them and working towards enhancing the quality of urban space, a substantial portion of these challenges can be addressed and resolved. When considering public interventions or assistance for informal settlements, it is crucial to recognize that these areas are not empty canvases. The layout and architecture of the settlement are shaped by the thoughtful strategies of its residents, who have developed them to address their resource limitations, needs, and aspirations. A significant drawback of informal settlements is the lack of non-commercial communal spaces, largely due to limited public intervention. However, this absence of public oversight might also allow residents more freedom from building regulations and spatial requirements that are often unaffordable and can hinder opportunities for the poorer population. Therefore, the self-built aspect of these communities should be seen as a foundation for planning efforts in informal settlements rather than a barrier (Pojani, 2019).

Approaches for improving informal settlements

Urban planning, as an independent and interdisciplinary field, can take significant steps to improve the quality of informal settlements. Planning, design, and implementation of infill development strategies contribute to the cohesion of the historical fabric, preservation of values, strengthening the physical structure, and enhancing sustainability. The role of urban planning can be broadly classified into two approaches: planning and design. The design approach typically encompasses six systems: physical form, public space framework, land use, movement and accessibility, views and vistas, and environmental considerations. On the other hand, the planning approach includes three systems: institutional management, socio-cultural, and economic aspects.

Urban design approach (design-oriented)

This approach can be understood through urban form systems, which encompass the physical structure, the framework of public spaces, movement and accessibility, land use, vistas, and environmental considerations. The application of various indicators from these urban form systems can initially facilitate the realization of infill development and, subsequently, improve the quality of urban settlements. Key factors influencing infill development within the physical form system include the quality of buildings, the age of buildings, the type of building structure, the number of floors, and the diversity in the architectural form of buildings (Nazarabadian *et al.*, 2024). The movement and accessibility network is one of the most significant factors affecting infill development, and its importance is further heightened in informal and peripheral settlements. Essential factors include access to various transportation modes (such as public transit), parking provision, the permeability of the urban fabric, and the degree of enclosure (Holden, 2019; Nazarabadian *et al.*, 2024; Dovey *et al.*, 2020). The land use system plays a pivotal role in the realization and effective implementation of infill development (Tabibian and Ghani, 2015). Key elements include integrating mixed-use functions, optimally utilizing reserved lands for infill purposes, and reclaiming and revitalizing derelict and abandoned sites (Aly and Attwa, 2013; Nazarabadian *et al.*, 2024). The urban landscape system is also a critical factor in reshaping the visual character of the urban fabric. Creating a distinctive and identity-

driven landscape can enhance the living environment for residents. Improving the legibility of the urban environment through the deliberate design of elements such as nodes, paths, edges, districts, and landmarks can significantly contribute to the success of infill development (Dovey & King, 2011). In the environmental system, key considerations include fostering climatic comfort, increasing the extent of vegetation and green spaces, maintaining cleanliness, and ensuring high standards of hygiene (Admasu, 2015; Beardsley and Werthmann, 2008; Kamalipour and Dovey, 2020). Factors affecting the enhancement of public spaces include demographic characteristics, decentralization of informal settlements, creation of diverse activities and features related to urban spaces such as proper separation of public and private areas, enhancement of place identity, and ensuring sufficient security (Kamalipour, 2023; Nazarabadian *et al.*, 2024; Kamalipour and Dovey, 2020).

Urban planning approach (planning-oriented)

Urban planning approaches can significantly influence the implementation and advancement of urban development, particularly with an infill development approach based on institutional management, socio-cultural, and economic systems (Carrilho and Trindade, 2022). Key components for revitalizing informal settlements include comprehensive planning and policy-making for urban areas in urban design. This component focuses on aspects such as urban governance and the characteristics of development plans (Admasu, 2015; Carrilho and Trindade, 2022). In terms of economic infrastructure, three key solutions include providing necessary economic facilities such as banking services to encourage residents to settle in urban areas, organizing and supporting small-scale vendors, fostering private sector economic participation, and controlling land prices and construction costs (Pourmosavi *et al.*, 2014). To strengthen social capital in these areas, it is vital to persuade residents to actively engage with complementary development projects and enhance collaboration and interaction among them. Adherence to higher-level documents and regulations established by supervisory authorities is proposed as a critical approach to ensuring compliance with the principles and laws set by governing bodies and regulatory documents (Boanada-Fuchs et al., 2024; Nazarabadian *et al.*, 2024).

Introduction to the study area

As shown in Fig. 7, the Noh-Darreh area is located in District 9, in the southwestern part of Mashhad, at the foothills of the southern mountains. Due to factors such as uncontrolled migration, unchecked development lacking necessary standards, and other contributing elements, this area has become one of the main zones for informal settlements in Mashhad. Over time, the area has suffered from physical and functional deterioration, and the lack of attention from urban authorities, coupled with the financial inability of residents to undertake renovation and improvement, has significantly exacerbated the situation. Given the extent and strategic location of Noh-Darreh, enhancing its physical and spatial qualities as an informal settlement zone is more urgent than ever. Noh-Darreh is highly suitable for infill development based on indicators of dilapidated fabric (such as old buildings, lack of standard construction, small plot sizes, unsuitable materials, etc.) and infill development opportunities (such as vacant and derelict land). It could serve as an ideal approach to improve the fabric in terms of physical form, infrastructure, public spaces, movement and access networks, visual aspects, land use, and environmental factors, ultimately leading to enhanced social sustainability, vitality, and revitalization of the area. If the infill development strategy proves successful, it will also prevent the unchecked spread of development in Noh-Darreh towards the southern heights of the Binalood mountain range. In this study, the urban planning and design factors influencing infill development have been identified, and the significance of each factor in the area has been assessed. After understanding the priority of dimensions and indicators for informal settlements in the study area, recommendations have been provided accordingly.

Findings

The components and indicators of urban planning and design, aligned with the infill development approach to enhance the quality of informal settlements in the Nah Dareh study area, are summarized in Table 2. To prioritize these indicators for implementation, taking into account the limitations of resources and capital, expert opinions were consulted, as explained in the research method section. According to the assessment of the research

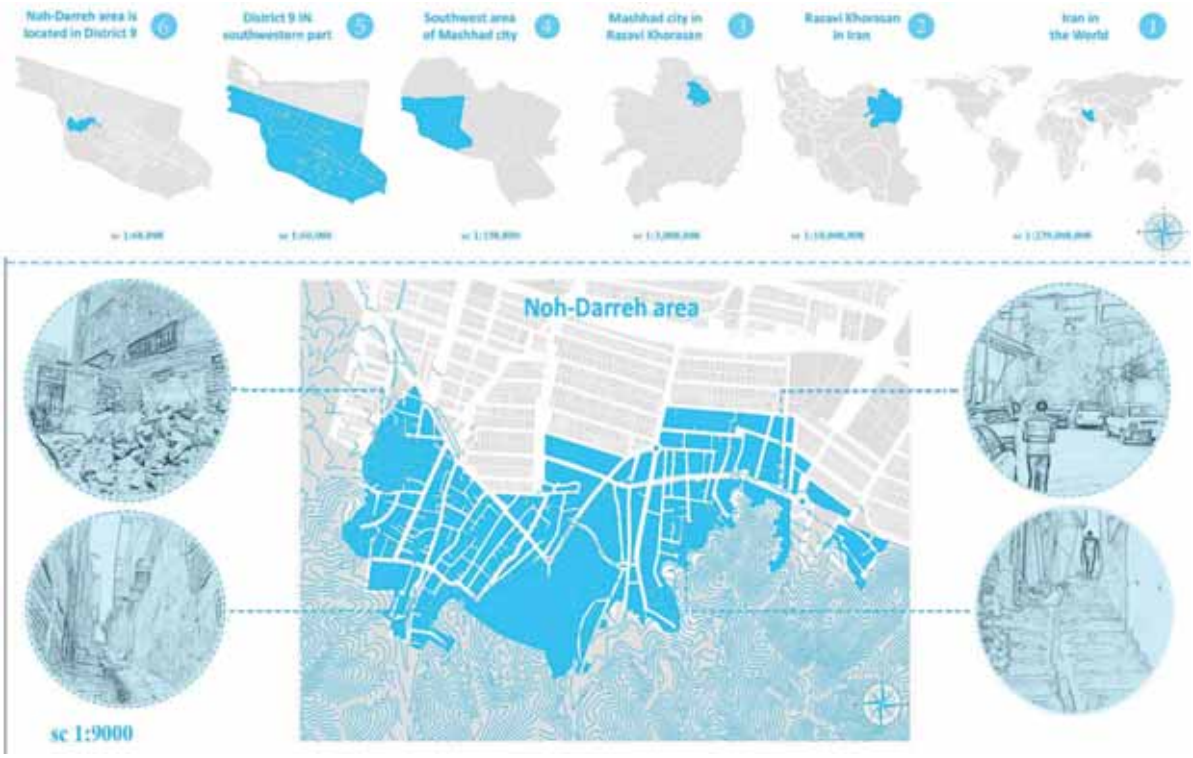

Fig. 7: Location of the study area

components, which was discussed in detail in the research method section, and according to Fig. 8, five systems of framework of public spaces (impact coefficient 0.244), land use (impact coefficient 0.214), movement and access (impact coefficient 0.138), physical form (impact coefficient 0.114), and institutional-management (impact coefficient 0.111) are among the most important and influential factors from the perspective of the infill development approach to improve the quality of the Noh-Darreh area as an informal settlement. The components that significantly influence the research goal include the Type of Function and Use of the Land (impact coefficient of 0.166), Building Features (impact coefficient of 0.114), Permeability of the Fabric (impact coefficient of 0.107), Quality of Urban Spaces (impact coefficient of 0.091), and Activity Characteristics (impact coefficient of 0.088). It is important to consider the impact of each component, as this can facilitate faster implementation of infill development and enhance the quality of living conditions. The realization of infill development in informal settlements, particularly in Noh-Darreh, Mashhad, requires attention to both planning and design approaches. According to the study findings, design-oriented systems, with a cumulative impact factor of 0.764, are considered more important than urban planning systems, which have an impact factor of 0.236. The type of function and use of land has a significant impact on infill development. The presence of brownfields, abandoned and degraded lands, wastelands, urban reserves, and multifunctional lands plays a crucial role in implementing the infill development approach, particularly in the context of Noh-Darreh, an informal settlement. For instance, repurposing brownfields—typically consisting of abandoned and polluted industrial sites—helps alleviate pressure on natural lands. Additionally, rehabilitating abandoned residential buildings not only enhances safety and security but also reduces crime and helps prevent the expansion of informal settlements. In the section on building characteristics, it is important to note that old buildings with poor structural quality that require demolition or renovation play a significant role in

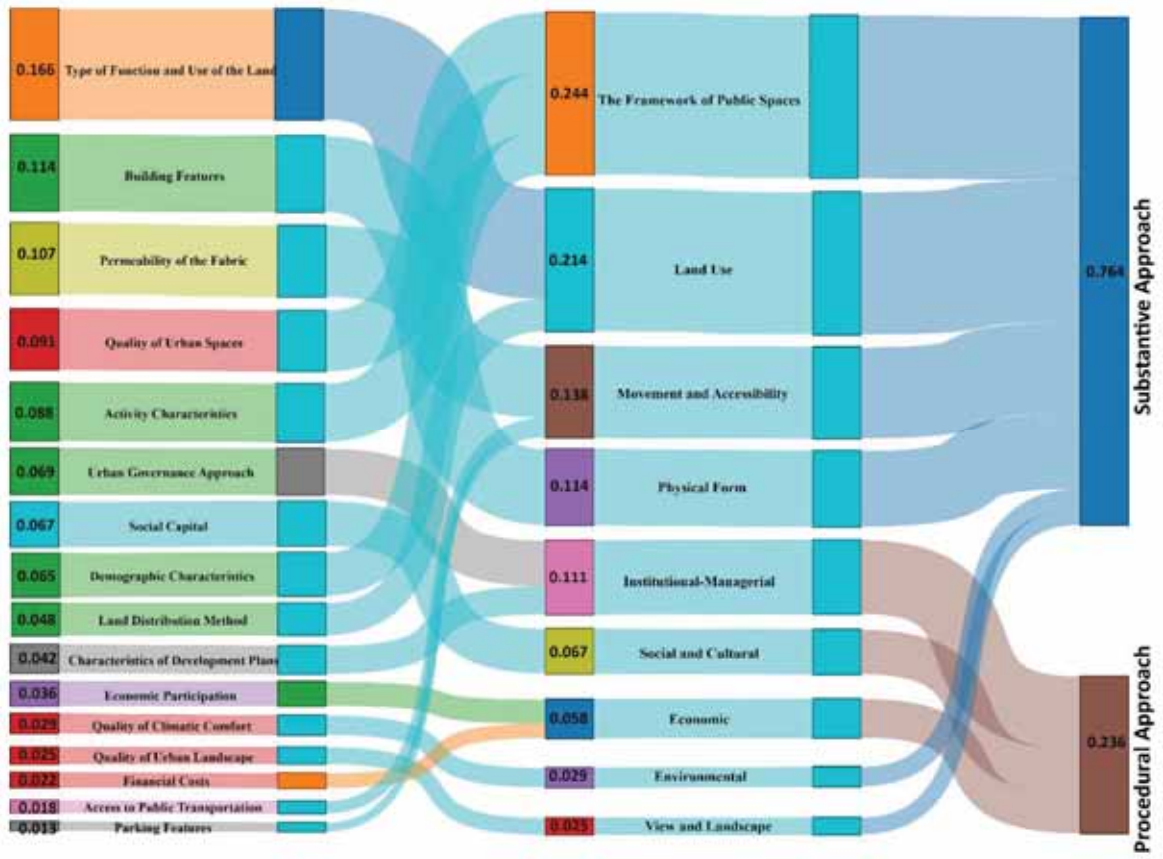

Fig. 8: Assessment of the importance of components, systems, and urban planning and design approaches influencing infill development for improving the quality of informal settlements in the Noh-Darreh area

facilitating infill development. These buildings can be integrated into the existing urban fabric through renovation and redevelopment, which helps to limit the expansion of the Noh-Darreh area beyond its current boundaries. This approach not only helps preserve the historical identity of the area but also reduces the excessive consumption of natural land by minimizing the need for new development on the outskirts of the city. As a result, it leads to more sustainable and efficient urban development. High permeability in urban areas allows residents to easily reach public services, recreational facilities, shopping centers, and public transportation. This improved access can enhance social and economic interactions, thereby increasing the demand for infill development. Additionally, adequately wide and easily accessible streets support potential changes and improvements in the area. The quality of urban spaces plays a crucial role in fostering a strong sense of place and security. When residents feel safe and connected to their neighborhoods, they are more likely to invest in and participate in efforts to improve and develop their community. This sense of belonging can also increase their willingness to continue living in the area. Activity characteristics significantly influence infill development. Key factors include activity diversity, vitality, the location of gathering spots, behavioral trends, and the compatibility of different activities. For instance, having a diverse range of activities within a neighborhood encourages pedestrian access and fosters social interactions among residents. This increased familiarity with neighbors can enhance residents' sense of commitment and belonging to their community, motivating them to improve their quality of life through initiatives like self-improvement, reconstruction, and renovation. These efforts can create more opportunities for effective infill development. Additionally, revitalizing dilapidated

Table 3: Proposed solutions related to urban planning and design for the Noh-Darreh area

Purpose	Approach	System	Proposed Solutions
Improving the Quality of Informal Settlements in the Noh-Darreh Area of Mashhad through an Infill Development Approach	Design-oriented	Framework of Public Spaces (0.244)	1. Managing population density in the Noh-Darreh area to prevent development on natural lands and highlands while implementing an infill development approach to enhance services for the existing population. 2. Developing various activities (commercial, medical, educational, etc.) in barren, abandoned lands using an infill approach to provide services and reduce the need for expansion. 3. Encouraging a sense of vitality and security enhances residents' connection to their community, motivating them to improve, renovate, and rebuild their homes. 4. Public spaces play a significant role in enhancing residents' desire to remain in their neighborhoods by offering opportunities for social interaction and creating cultural attractions. This sense of community motivates residents to work towards improving the living conditions in these areas. 5. Ensuring a clear separation between public and private spaces, along with compatible activities, can enhance the quality of life in existing areas and prevent the proliferation of horizontal development.
		Land Use (0.214)	1. Transforming neglected, abandoned, and underutilized lands to provide essential services and enhance community well-being. 2. Constructing social housing for low-income groups enhances access to safe housing and supports infill development, reducing the expansion of slums and informal settlements. 3. Utilizing multi-functional land use to enhance service delivery. 4. Equitable distribution of land and services, effective land use management, and enhanced access for various groups to urban spaces can foster infill development.
		Movement and Access (0.138)	1. Improving pedestrian access to public transportation, managing parking, reducing reliance on private cars, enhancing mobility, and elevating quality of life contribute to successful infill development. 2. Enhancing permeability allows residents better access to services, which ultimately boosts their willingness to renovate and rehabilitate dilapidated, abandoned, and unused buildings.
		Physical Form (0.114)	1. Utilizing old, dilapidated, and structurally unsafe buildings for reconstruction and renovation aligns with the infill development approach to prevent horizontal expansion of the Noh-Darreh area. 2. Raising the maximum building height to four floors can provide sufficient housing and services while preventing horizontal expansion of the area. By limiting this type of development, we can protect natural land and enhance the quality of life for residents in the Noh-Darreh area.
		Environmental (0.029)	1. Enhancing cleanliness and hygiene in the environment, vegetation, and open green spaces improves the quality of life and encourages residents to engage in infill development projects.
		View and Landscape (0.025)	1. Enhancing the readability of urban areas through Lynch's elements facilitates navigation and orientation. This improvement makes urban spaces easier to use and provides better access to various services, ultimately leading to an improved quality of life. As a result, residents are more inclined to live in the neighborhood, which contributes to better living conditions in their homes.
	Planning-oriented	Institutional-Managerial (0.111)	1. Land allocation through formal institutions and adherence to land use plans are some of the most effective methods for promoting infill development and reducing the need for new land acquisition.
		Social-Cultural (0.067)	1. Involving the community in decision-making and project implementation can enhance transparency. This greater transparency can foster trust among residents. 2. Enhancing residents' understanding of the benefits of infill development, such as optimal use of existing infrastructure, reduced reliance on private cars, and improved access to services, fosters higher resident participation and satisfaction. 3. Greater attachment to a place fosters social participation and cooperation among residents, which in turn contributes to the success of infill development programs.

Table 3: Proposed solutions related to urban planning and design for the Noh-Darreh area

Purpose	Approach	System	Proposed Solutions
		Economic (0.058)	1. Infill development utilizes the city's existing resources and revitalizes neglected areas, creating new job opportunities and increasing residents' income levels. 2. Reduced construction costs in infill development because they include the expenses of renovating and improving existing buildings. These costs are often lower than constructing a new building on vacant land. 3. Revitalizing dilapidated structures through infill development utilizes existing land effectively, reducing costs related to purchasing new land, optimizing the use of current infrastructure, and lowering construction expenses.

areas and repurposing wasteland by introducing a variety of activities can enhance the quality of life in informal settlements. Transforming these neglected spaces into vibrant areas not only saves resources but also promotes social interactions and improves living conditions for residents. In response to the second research question, Table 3 outlines the proposed solutions using both design-oriented and planning-oriented approaches to address the components and indicators of infill development. These proposals take into account the characteristics of the dilapidated fabric and inadequate physical quality of the Noh-Darreh area. Implementing these solutions through infill development could effectively tackle the issue of informal settlements in the Noh-Darreh area. Each solution is detailed according to its specific system.

Differences between this research and previous studies

This study aligns with the three articles from Mashhad, Ardabil, and Tabriz, focusing on infill development and overarching goals such as improving quality of life, preventing urban sprawl, and optimizing land use. However, the key differences lie in the scope of the study and the prioritization of indicators. While the article from Mashhad emphasizes historical context and the Tabriz article focuses on historical commercial complexes, this study examines the informal settlement of Nah Darreh. It provides a quantitative impact factor for the research indicators and addresses the physical and social challenges more practically. Additionally, unlike the Ardabil article, which addresses the degradation of marginal lands, this study suggests integrated solutions for enhancing informal settlements. Therefore, rather than conflicting with the other articles, this study complements them by focusing on less-explored areas and offering an implementation model. The main difference between this study and previous research lies in its shift from merely describing physical characteristics to offering operational, development-oriented solutions. While earlier studies, such as those conducted in Mumbai, Caracas, and Medellin, primarily focused on the morphological analysis and physical attributes of informal settlements, this study takes a significant step forward. It employs an infill development approach that systematically addresses the functional and spatial improvement of these areas. By integrating environmental quality criteria—such as permeability, security, and diversity of activities—with effective quantitative indicators, this research not only bridges the gap between theory and practice but also paves the way for targeted interventions in informal contexts. It provides a planning framework based on prioritization, allowing for more focused and effective improvements. In summary, this study progresses from mere description (what) to explanation (how to improve).

CONCLUSION

Today, informal settlements are one of the primary challenges in urban planning and development, with their negative impacts imposing significant material and immaterial costs on cities. The displacement of residents and their replacement with migrants, illegal constructions, increased instability, unchecked population growth, degradation of the urban landscape, rise in social crimes, reduced sense of belonging, and many other related issues are just a few of the problems caused by informal settlements within urban fabrics. The lack of strong regulations and oversight in recent years has turned the Noh-Darreh area into an informal settlement. The Noh-

Darreh area is a deteriorated urban fabric with old buildings, non-standard structures, small plot sizes, poor-quality materials, and more. However, specific opportunities within Noh-Darreh, such as vacant, brownfield, abandoned, and derelict lands, as well as urban reserve and development lands, can be leveraged through the infill development approach to enhance the quality of the urban environment. Therefore, despite the presence of vacant, degraded, and development-ready land, there is still hope for altering the future development trajectory. Infill development can prevent the uncontrolled expansion of the Noh-Darreh area towards the southwest hills and environmental degradation. As an effective approach, it can slow down the spread of informal settlements and initiate targeted, sustainable development to improve residents' quality of life and living conditions. Based on these results, creating a connected system of public spaces, strengthening the spatial structure, proper land use planning (based on matrices of compatibility, desirability, capacity, and interdependence), developing an integrated network of transportation routes, identifying potential lands, and incorporating suitable physical, functional, and activity-related interventions can significantly change the urban fabric's appearance and create a unique identity. These actions will also increase residents' participation in the development process. Furthermore, it is crucial for responsible institutions to not only focus on the preparation of an urban development strategy but also to work toward attracting investors and collaborating to address the needs of the residents. While informal settlement has been the focus of numerous studies, the potential of infill development to address this issue has largely been overlooked. This research, which considers both design and planning approaches, provides a comprehensive model of the urban planning and design factors necessary to enhance the quality of informal settlements in Noh-Darreh, Mashhad, through infill development. The urban planning and design solutions outlined in Table 3 can contribute to improving the quality of living in Noh-Darreh through the successful implementation of infill development. It is evident that examining this issue in other existing informal settlement examples in Iran and globally could further refine, validate, and generalize the findings of this study. The research has several limitations, including a lack of scientific resources on the topics of infill development and informal settlements. Additionally, there is insufficient attention given to the role of urban design and planning in enhancing the quality of informal settlements through an infill development approach in previous studies. It is recommended that future research explore in greater detail how each identified indicator impacts infill development in informal settlements. Moreover, the interactions between these indicators and their reciprocal effects should be examined. Finally, the findings from the Noh-Darreh area should be compared with those from other similar locations.

AUTHOR CONTRIBUTIONS

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Mahdieh RazmaraMina, Morteza Nazarabadian, Seyed Amirmohammad Poorsarvghad, and Ali Asghar Pilehvar. The first draft of the manuscript was written by Morteza Nazarabadian and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

AHP	Analytic Hierarchy Process
Glynn's tool	The Glynn tool is a standard checklist used to assess the validity and reliability of library research.
Snowball sampling method	It is a sampling method in which primary participants (key experts) refer the researcher to other relevant individuals in the expert network.
Expert Choice	Expert Choice software is an application for pairwise comparison calculations to solve the analytic hierarchy process problems.
PRISMA	The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) reporting guidelines are designed to improve the reporting of systematic reviews. PRISMA assists authors to completely report why their systematic review was done, what methods they used, and what they found.

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ORIGINAL RESEARCH PAPER

Planning and design strategies for enhancing passive defense in future cities during wartime

H. A. A. Hussein

Architectural Engineering and Urban Planning Department, Faculty of Engineering, Port Said University, Port Said, Egypt

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ABSTRACT

BACKGROUND AND OBJECTIVES: The future of warfare is expected to be increasingly urban. Recent conflicts have demonstrated that cities have become central battlegrounds due to their dense populations, critical infrastructure, and strategic value. Traditional defense mechanisms, such as perimeter fortifications, have proven insufficient against evolving warfare tactics. Despite this growing threat, current urban planning and design practices often prioritize economic and functional aspects, neglecting passive defense measures. To address this gap, this research explores urban planning and design strategies for future cities to enhance their passive defense capabilities, helping them withstand and adapt to enemy attacks while promoting the well-being of their residents.

METHODS: An analysis of the early stages of two ongoing conflicts was conducted to recognize the contemporary behavior of attacks. A literature review was then undertaken to explore peer-reviewed research on passive defense strategies and measures for mitigating these attack behaviors. Based on the findings, planning and design criteria were proposed, and corresponding planning components were identified. Finally, planning and design strategies were developed to enhance the resilience of future cities against potential attacks. The methodology is more qualitative, with references as the basis of analysis and further discussion.

FINDINGS: The study showed that landscape planning and design (22.7%) and urban design (21.3%) were the most frequently identified components in mitigating the effects of attacks. Urban network planning (17.3%), land use planning (14.7%), and architectural design (14.7%) followed. However, this does not necessarily mean that these components are the most influential in enhancing the passive defense capabilities of future cities, but rather that their impact spans multiple aspects. Additionally, the study highlighted several key strategies for improving the passive defense capabilities of future cities against potential attacks. These include prioritizing naturally protected sites, maintaining low population density, utilizing multiple network patterns and street shapes with T-junctions, implementing an unpredictable polycentric distribution of targets, integrating renewable energy and portable infrastructure solutions, designing homogeneous short blocks with low building density and point-building typology, incorporating low-rise stepped or tapered buildings with rounded corners, centering basements, employing blast-resistant structural systems, and using low-emissive, blast-resistant materials and coatings.

CONCLUSION: Effectively integrating these strategies into future cities requires governments to establish legal frameworks, strengthen interagency coordination, update planning and building codes, mandate passive defense in new construction, incentivize private sector participation, and secure dedicated funding. Moreover, prioritizing citizen education on passive defense, promoting community preparedness, and ensuring effective communication with residents are required.

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44	13	2

*Corresponding Author:
Email: *heba.adel@eng.psu.edu.eg*
Phone: +201005485923
ORCID: 0000-0001-9062-7015

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INTRODUCTION

Recent conflicts have highlighted the increasing vulnerability of cities in modern warfare. Their dense populations, critical infrastructure, and strategic value make them prime targets (Shakibamanesh, 2015a). As urbanization accelerates, with nearly two-thirds of the world's population projected to reside in urban areas by 2040, up from 56% in 2020, future conflicts will likely be predominantly urban (Weissmann, 2023). This growing threat underscores the urgent need for proactive strategies to enhance the resilience of future cities and protect their assets and inhabitants from potential attacks. A key component of these strategies is passive defense, a set of measures that seeks to limit the damage resulting from an attack or disaster without directly confronting the threats. These measures can include the construction of fortifications and barriers, disguising critical assets, establishing early detection and warning systems, developing emergency plans, and equipping individuals with the readiness required to face threats (Niknam and Kayedpour, 2015). Passive defense measures generally require less equipment and fewer facilities than active defense, making them more cost-effective. Moreover, they are designed to last for decades, making them a more sustainable option for long-term protection. Furthermore, they do not require active engagement or direct intervention with threats, reducing the risk of escalation and collateral damage (Asl *et al.*, 2019). Recently, passive defense has received increasing attention in urban studies as a critical strategy for protecting cities during wartime. Shakibamanesh (2015a) outlined the requirements for safe cities under war conditions, emphasizing how passive defense strategies related to urban form can reduce damage and casualties. His findings highlighted the role of urban patterns, building arrangements, and parcel sizes in mitigating the impact of attacks. Salehi *et al.*, (2017) introduced various methods to enhance the security of urban public spaces and inter-building areas using passive defense principles. These methods included enclosing spaces with walls, incorporating floor level differences and rows of trees, creating safe corners for shelter, and using blast pockets and bends to disrupt blast waves. Shakibamanesh and Ghorbanian (2017) explored passive defense measures for improving the resilience of major transportation terminals during wartime. Their key recommendations included using dense vegetation for camouflage and establishing safe buffers around terminals to limit the impact of explosions and fires. Karami *et al.*, (2020) identified critical factors affecting the vulnerability of sensitive and vital centers to attacks, highlighting the importance of passive defense considerations in site selection. These factors included site elevation, slope direction, and distance from borders, rivers, faults, and road networks. Amou *et al.*, (2023) analyzed factors increasing the severity of damage in residential areas during attacks, using a passive defense approach. Their identified factors included population and building density, number of floors, building materials, building age, street width, and accessibility to open spaces and critical services. Despite this growing body of research, contemporary urban planning and design practices frequently prioritize aesthetic considerations, economic development, and sustainability objectives, often neglecting the crucial dimension of wartime resilience (Brodey, 2024). In this context, this study explores urban planning and design strategies to enhance the passive defense capabilities of future cities during wartime. Strengthening these defenses can boost the population's sense of security and confidence by reassuring them that their city is well-prepared for potential threats. Research suggests that perceived safety and preparedness contribute to community resilience, psychological well-being, and lower stress levels associated with uncertainty and risk. Additionally, effective passive defense measures can improve a city's ability to manage, mitigate, and recover from wartime devastation, ultimately promoting long-term urban stability (Awada, 2014). To achieve this, the study analyzes contemporary attack behaviors and target characteristics. It then examines passive defense measures to mitigate the effects of attacks and protect targets, proposes planning and design criteria based on these measures, identifies planning components fulfilling these criteria, and develops strategies aiming at enhancing the passive defense capabilities of future cities. The study focuses on two ongoing conflicts: the Russia-Ukraine conflict, which began on February 24, 2022, and the Israel-Palestine conflict, which began on October 7, 2023. Data for these conflicts was collected up to May 22, 2024.

MATERIALS AND METHODS

Analysing recent conflicts

Russia-Ukraine conflict

On February 24, 2022, Russia launched heavy shelling and airstrikes on Ukraine using aircraft, missiles, and long-range artillery, followed by a major land invasion (Rawtani *et al.*, 2022). Drones have been used in real-time reconnaissance and surveillance missions, bombing campaigns, guiding artillery bombardment, as well as video recordings feeding directly into information operations. Since the beginning of the military operation, the Russian attacks have targeted the military infrastructure of the Ukrainian Armed Forces (e.g., military airfields and air force) to weaken Ukrainian defense capacity. Soon after, Russia appeared to shift many of its attacks toward critical infrastructure. In this context, major roads, bridges, railways, and airports have been destroyed to obstruct the transport of military equipment. Power plants, oil storage facilities, and gas pipelines have also been targeted (Peptan, 2022). In addition, the Russian Armed Forces began targeting residential buildings. According to the calculations by Kyiv School of Economics (2023), since the beginning of Russia's war against Ukraine, 17.5 thousand high-rise buildings and 136 thousand private houses have been damaged as of February 2023. Calculations also showed that more than 50% of the housing stock in a significant number of cities was damaged or destroyed, which requires a comprehensive restoration of these cities. The initial engagements took place in both the open, relatively flat terrain of the Ukrainian countryside and the lighter urban terrain, where Russian military forces advanced rapidly (T, 2022). This encouraged Russian ground troops to continue moving toward the capital city of Kyiv, the heart of Ukraine and the seat of the government. However, their advancement has been slowed down significantly. Kyiv is surrounded by terrain that hinders the movement of large-scale troops. Moreover, forests, rivers, and urban areas around it were turned into strongholds of resistance (Havrylets, 2023; Mhugos, 2022). Furthermore, much of the network leading to Kyiv is composed of narrow winding roads that would ensnare vehicles and require greater fuel consumption. All these factors forced Russian convoys to take certain routes, where they were exposed to hit-and-run raids using mines, machine guns, and missiles. This blocked the Russian military forces' advance and made Ukrainians reclaim a series of towns outside the capital (Mhugos, 2022; Sonne *et al.*, 2023; T, 2022). Since then, skirmishes have continued between the two sides.

Israel-Palestine conflict

On October 7, 2023, Hamas launched an unprecedented attack – named Operation Al-Aqsa Flood – on Israel in response to the Israeli army's crimes against the Palestinians and its repeated incursions into the Al-Aqsa Mosque in Jerusalem. In this attack, Hamas fired thousands of rockets from Gaza toward Israel, while others tore down several parts of Israel's high-tech separation fence on the Gaza boundary, infiltrated into neighborhoods/settlements inhabited by Israelis, and detained many hostages. The following day, Israel declared a state of war and launched air and artillery strikes on what it called Hamas targets in northern Gaza (Elkahlout, 2024). Satellite imagery and drone footage were used to identify potential targets (Khalifa, 2024). In early strikes, four large high-rise towers in Gaza City were targeted and destroyed, including Palestine Tower, al-Hashem Residential Building, Wattan Tower, and Al Aklouk Tower (We4gaza crew, 2023). Targeting high-rise towers piled up the dead bodies of the Palestinians and overwhelmed the healthcare system (Billah, 2023). Besides the high-rise towers, strikes targeted several low-rise buildings, ambulances, hospital yards, mosques, churches, water and sanitation facilities, and UNRWA Schools (Alarabiya crew, 2023; We4gaza crew, 2023). Soon after, Israel imposed a siege to block food, water, and fuel from entering Gaza, and starvation was used as a weapon (Ebrahim *et al.*, 2023). On October 13, the Israel Defense Forces ordered residents of northern Gaza to evacuate southward in anticipation of an impending ground invasion. As a result, thousands of Palestinians, alongside thousands of wounded, sheltered at schools and hospitals where they believed they would be safe. However, on October 17, one of these hospitals, "Al-Ahli Baptist Hospital," was hit. On October 27, the Israel Defense Forces launched its ground invasion, accompanied by a telecommunications outage, disrupting internet and telephone access to, from, and within Gaza (The New Arab Staff & Agencies, 2023). The purpose of this invasion is to cordon off Gaza City from various directions until it is entirely isolated from the south

of the Strip, then to continue advancing toward the city center and gradually occupy the city. On November 7, Israeli troops encircled Gaza City. Since then, they have been entering the built-up areas of Gaza slowly. This is due to the narrow streets, which made it difficult for tanks and other armored vehicles to maneuver through, and reduced the effectiveness of air support, leaving Israeli forces vulnerable to attacks by defenders (The Arab Center for Research and Policy Studies, 2023).

Both conflicts show that:

- *The dominant military action in attacking strategic targets is air and artillery strikes. These strikes aim to reduce the opponent's defensive capacity in preparation for the ground invasion, which comes in the next stage.*
- *Both air and artillery strike depend heavily on aerial detection of potential targets.*
- *Strategic targets include military infrastructure, critical infrastructure, and areas likely to contain a large number of people (e.g., high-rise buildings and shelters).*
- *Ground invasion can reduce the strength of the attacker, even if it is a superior military force.*

Based on the above, this study focuses on passive defense strategies and measures to protect targets from aerial detection and minimize damage from air and artillery strikes in case of being attacked. Military targets have been excluded from the study, as they are usually too well protected to be attacked. The focus of this study is on civilian infrastructure and population centers.

Reviewing passive defense measures

Protecting high-value targets from aerial detection

Reducing the visibility of high-value targets from the air can significantly decrease their vulnerability to attacks. Sardari and Kiani (2018) discussed how the proximity of targets to reference points such as highways, major roads, coastlines, rivers, and borders makes their locations more susceptible to enemy detection. Therefore, selecting appropriate locations for such targets during city planning can enhance their protection. Shakibamanesh (2015a) argued that regular street networks make targets easily distinguishable from the air, facilitating systematic aerial operations. In contrast, irregular networks introduce unpredictability, making navigation and target identification more difficult for aerial forces. He also suggested that high-value targets should be integrated into the urban fabric in a way that minimizes contrast with surrounding structures. To achieve this, maintaining homogeneity in block shapes and sizes should be considered. Research has also shown that certain geometric properties make high-value targets vulnerable to aerial detection. For example, Saeedi *et al.*, (2023) and Shakibamanesh and Ghorbanian (2016) highlighted that the long, linear shapes of airport runways and major roadways make them easily identifiable from above. Camouflage techniques, such as applying green-colored asphalt or artificial grass on runways and strategically planting vegetation along transportation corridors, can help disrupt their visual signature. Abad (2017) and Crotogino (2022) found that critical infrastructure, encompassing water, oil, and gas facilities, presents vulnerabilities due to the large, often regularly shaped structures and associated heat emissions. Undergrounding these installations, integrating them into the landscape with dense vegetation, and employing architectural concealment techniques (e.g., painting them in colors that blend with the natural environment) can offer robust protection. Gubbi *et al.*, (2017) and Yahya (2019) argued that telecommunications and power systems, including Base Transceiver Stations (BTS) and substations, are susceptible due to their height, metallic reflections, and regular spacing. Camouflaging BTS towers as natural elements (e.g., trees) or urban features (e.g., streetlights) and transitioning power lines and substations to underground can greatly enhance their protection against aerial attacks. Vardanyan (2022) pointed out that the considerable height and shadow projections of high-rise buildings make them conspicuous targets. To address this, irregular vegetation, coarse-textured ground mats around building bases, and innovative architectural techniques, such as LED façade projections that create an illusion of transparency, can help obscure their form. Besides the aforementioned measures, Zargar *et al.*, (2019) discussed that the application of high radar cross-section materials on facades (e.g., metals) needs to be minimized. This can mitigate the reflected radar energy toward the signal source, making target identification more difficult.

Minimizing damage from air and artillery strikes in case of being attacked

Damage from air bombing and missile attacks

can destroy buildings and infrastructure, block streets, impede firefighting operations, hamper the evacuation procedure, and hinder access to hospitals and rescue centers, leading to more injuries and casualties (Shakibamanesh, 2015a):

To reduce building damage and the associated risk of injury or death, Shakibamanesh (2015a) argued that dispersing buildings and functions, especially high-value targets, makes the attackers need to make frequent attacks and use more destructive weapons to hit them. This could increase economic pressure on the attacking forces, which might make the attackers retreat. Awada (2014) discussed that limited building heights can encourage the horizontal distribution of inhabitants, thus decreasing the number of kills and injuries if these buildings were attacked. Vardanyan (2022) indicated that, during attacks, freestanding buildings might reduce the risk of progressive collapse that can occur in attached buildings where the failure of one structure can impact adjacent ones. Shyshkin and Pankeieva (2024) recommended that buildings should be designed to be more resistant to destruction through various construction techniques and materials. Salehi *et al.*, (2017) pointed out that terraces and shades may detach from buildings when bombed, collapse away from them, and hit pedestrians and passersby; therefore, they should be reduced. Moreover, they indicated that glass facades and large windows should only be used with protective measures (e.g., using ballistic glass) to mitigate the risk of glass shards being thrown around if targeted. Furthermore, they emphasized that well-placed trees around buildings can act as natural shields against shrapnel from explosions. In addition, they highlighted the importance of providing immediate refuges in urban spaces. These refuges should be designed to accommodate the prone position, which is the safest body posture during an explosion. Immediate refuges may include curved walls, flower boxes, and benches.

To reduce infrastructure system failure, Shiri and Golestaneh (2015) and Zarghani and Shadmehri (2016) discussed the significance of placing power transmission lines, water, and gas pipelines at a suitable depth from the ground to mitigate the devastation caused by bombing and missile attacks. Shakibamanesh (2015a) and Zarghani and Shadmehri (2016) pointed out the importance of using looped/ hybrid infrastructure systems as they block the flow of water or gas only in the damaged parts if attacked, while it continues to the other parts of the city. On the contrary, in dead-end or tree systems, the water or gas flow all over the city can be blocked if one part of the system is attacked and damaged. In this regard, Shakibamanesh (2015a) highlighted that looped/ hybrid infrastructure systems are usually implemented in non-linear cities, while dead-end or tree systems are usually adopted in linear cities. Zarghani and Shadmehri (2016) recommended equipping buildings with independent systems to generate electricity locally in case conventional power sources have been destroyed.

To reduce the extension of explosions and fires, Modiri *et al.*, (2016) and Shakibamanesh and Ghorbanian (2017) discussed the importance of placing potentially explosive targets (e.g., airports and gas stations) outside cities and creating a safe buffer around them with dense vegetation. Ratcliff *et al.*, (2023) noticed that decreasing the width of streets or increasing the height of buildings along them could increase explosion damage. Accordingly, wide streets with low-rise buildings on either side represent one of the safest environments in case of an explosion. Drazin (2017) indicated that the intensity of the blast wave in a cul-de-sac is the greatest, while the crossroads produce the least. Hence, the more openings available for the explosion to expand into, the less effect it will have. However, this could potentially increase the radius of the explosion and affect more buildings and people, even if the pressure is lower. Chi *et al.*, (2021) argued that increasing the space between buildings can create venting openings, helping to reduce the impact of explosions on the surrounding environment. Also, Salehi *et al.*, (2017) discussed that using curved corners in buildings can divert and minimize the wave of the explosion. Mohammadpour *et al.*, (2017) argued that channeling winds can accelerate wind speed by about twice and provide more oxygen to fuel fire, contributing to fanning flames and carrying embers to ignite new fires in other locations. Therefore, curved or meandering streets, well-placed windbreaks/firebreaks (e.g., multi-layered vegetation and walls), and staggered building arrangements must be considered.

To reduce injuries and casualties during attacks, the evacuation of vulnerable civilians and settling them in safe shelters is crucial for their survival

and well-being. Regarding the evacuation process, Tsai and Chang (2023) found that straight streets and few turns are more helpful for evacuation than curved streets and many turns. Evangelopoulos (2025) discussed that multiple evacuation routes should be considered to provide flexibility in case of obstructions or damage. Awada (2014) discussed concealing vehicular and pedestrian movements during evacuation using interlocking trees. Salehi *et al.*, (2017) highlighted the importance of keeping the streets and open spaces around buildings safe for evacuation and emergency shelter purposes. They estimated that the distance of the collapsing debris away from a building is equal to the height of the building. Moreover, they recommended that elements impeding (e.g., hard and muddy surfaces) or tripping (e.g., uneven patches or unnecessary steps, especially single steps) the movement of evacuees should be removed. Shelters can be parts of buildings or separate structures on- or underground (Shakibamanesh, 2015b). Salehi *et al.*, (2017) discussed that on-ground shelters can be placed in public urban spaces. They should be enclosed with resistant curved walls or floor-level differences to offer protection against shrapnel from explosions. Thick vegetation can also serve as a protective barrier, hiding shelters and obscuring them from the field of view in aerial detection. Awada (2014) argued that underground shelters should be located beneath open spaces, empty lots, and low-rise building basements. As for high-rise building basements, it was found that the more stories the building consists of, the more dangerous the basement is. He also recommended connecting underground shelters to building basements through underground tunnels to facilitate the process of evacuation. Shakibamanesh (2015a) indicated that shelters should be distributed in such a way that allows overlaps. Moreover, he argued that shelters can serve as both emergency shelters during wartime and as functional spaces in normal times to enhance their usefulness and reduce the overall cost. Subways and underground stores can be good examples of multi-purpose shelters. Shakibamanesh (2015b) recommended that the time it takes to access a shelter should not exceed 5 minutes.

RESULTS AND DISCUSSION

Planning and design criteria were developed based on the aforementioned passive defense measures. These criteria guided the identification of city planning components that can be used to develop strategies that enhance the passive defense capabilities of future cities (see Fig. 1). The findings highlight the critical role of site selection, population density, urban network planning, land use planning, infrastructure planning, urban design, landscape planning and design, and architectural design in shaping defensible future cities. Notably, landscape planning and design (22.7%) and urban design (21.3%) were the most frequently identified components in mitigating the effects of attacks. Urban network planning (17.3%), land use planning (14.7%), and architectural design (14.7%) followed (see Fig. 2). This does not mean that these components are the most influential in enhancing passive defense capabilities of future cities, but rather that their impact spans multiple aspects.

Drawing from the previous analysis, the proposed planning and design strategies to enhance the passive defense capabilities of future cities, based on city planning components, include the following:

Site selection

Selecting sites with natural barriers and limited reference points can enhance the passive defense of future cities by making them more difficult to locate, navigate, and approach.

Population density

Maintaining a low and evenly distributed population density in future cities can provide a passive defense advantage by dispersing inhabitants and minimizing casualties during an attack. This forces attackers to escalate to more frequent and destructive strikes, potentially increasing their costs and deterring further aggression.

Urban network planning

Network pattern: Integrating different network patterns in future cities can leverage their strengths while mitigating their weaknesses. Combining irregular and tributary patterns for stealth with gridiron, radial, and ring patterns for connectivity can make future cities harder to target yet easy to navigate during emergencies. This strategy can make future cities both defensible and functional, minimizing casualties and disruption during attacks.

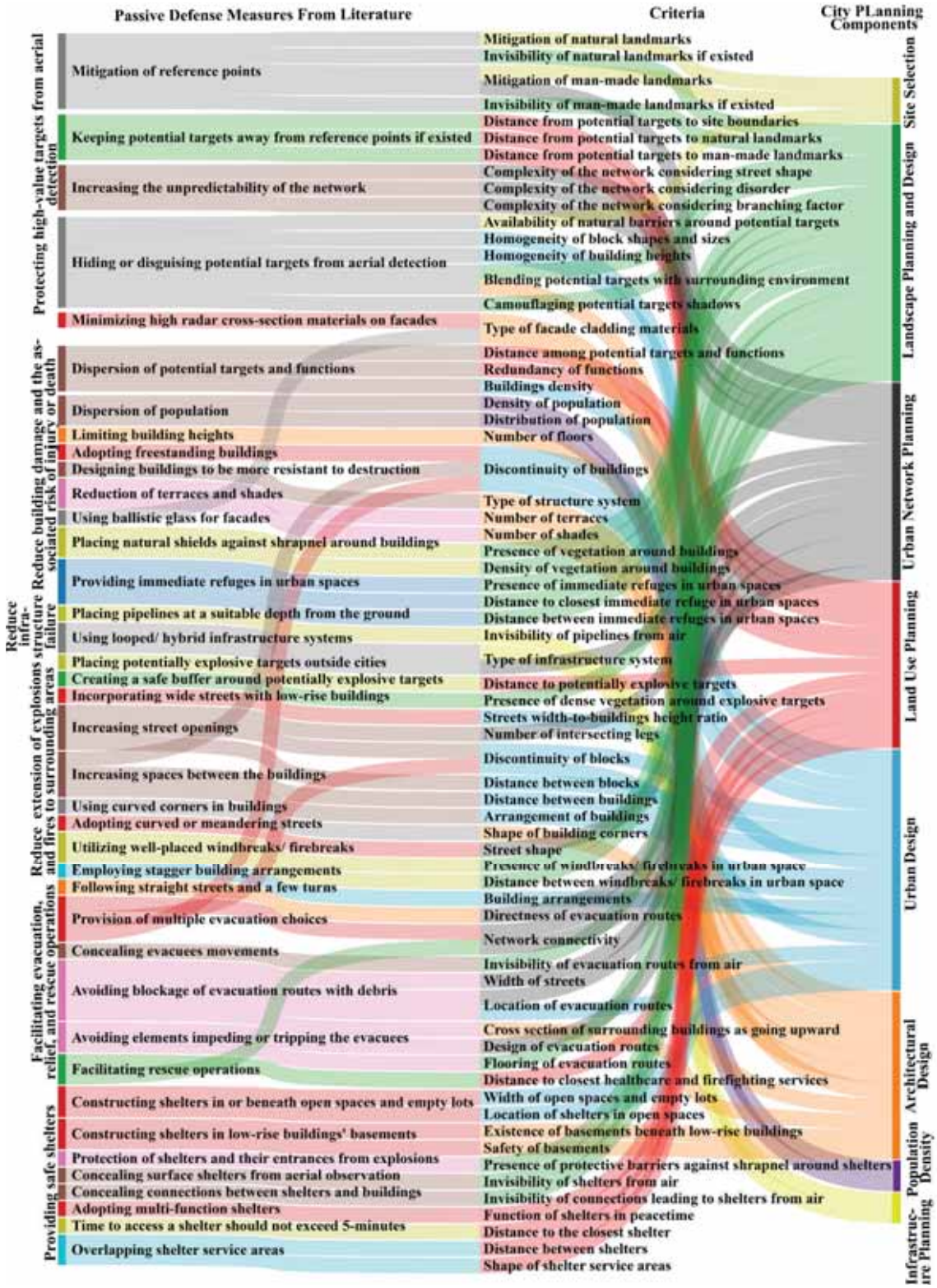


Fig.1: Planning components fulfilling passive defense measures

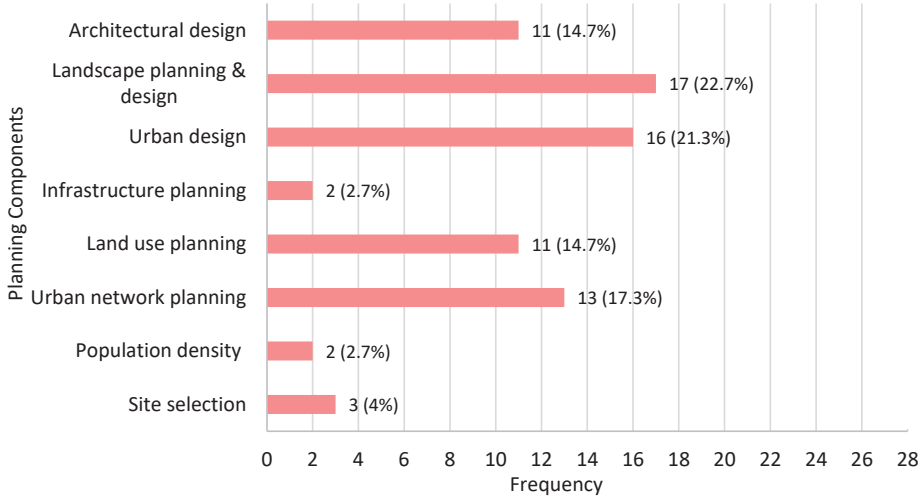


Fig. 2: Frequencies of city planning components in mitigating the effects of attacks

Table 1: The nexus between network patterns and passive defense measures

Passive defense measures and their indicators	Network patterns					
	Linear	Gridiron	Radial	Ring	Tributary	Irregular
Protect high-risk targets from aerial detection by:						
- Mitigation of man-made landmarks (e.g., urban spines and nodes)	○	●	○	○	●	●
- Complexity of the network considering disorder	○	○	○	○	◙	●
- Complexity of the network considering the branching factor	◙	○	○	○	◙	●
Reduce infrastructure system failures by using looped/ hybrid infrastructure systems.	◙	●	●	●	◙	●
Facilitating evacuation, relief, and rescue operations by ensuring strong connectivity between different parts of the network	○	●	◙	◙	○	○

● Fully achieved ◙ Partially achieved ○ Not achieved

The nexus between network patterns and different passive defense measures is presented in Table 1.

Street shape: Integrating linear streets for efficient evacuation with curved or winding streets to mitigate blast wave impacts can play a critical role in improving the defense capabilities of future cities. However, areas with predominantly linear streets are recommended to be supplemented with barriers (trees, walls, berms) to reduce blast wave impacts. Conversely, in areas with predominantly curved or winding streets, the focus is suggested to be on developing and implementing comprehensive mass evacuation plans, including designated routes and clear signage. Table 2 shows the nexus between street shape and passive defense measures.

Street openings: Prioritizing T-junctions in future

Table 2: The nexus between street shape and passive defense measures

Passive defense measures and their indicators	Street shape		
	Linear	Curved	Winding
Protect high-risk targets from aerial detection by increasing the complexity of the network.	○	●	●
Reduce the intensity of the blast and the extension of fires to surrounding areas by diverting blast waves and fire flames.	○	●	●
Facilitating evacuation, relief, and rescue operations by increasing the directness of streets for rapid evacuation	●	○	○

● Fully achieved ◙ Partially achieved ○ Not achieved

cities can enhance passive defense by balancing blast wave mitigation and multiple evacuation choices. While crossroads offer similar functionality, they can become points of congestion during mass evacuations due to decision-making challenges. The optimal distance between street openings depends on several factors, including the type and amount of explosive, street width, building height, and the presence of barriers.

Street design: To facilitate evacuation, relief, and rescue operations, prevent street blockage, and improve accessibility, it is recommended that the minimum width of any street be the combined height of the tallest buildings on either side, plus two 1.5m wide step-free walkways and two 3.5m wide travel lanes. This width allows sufficient space for emergency vehicles to maneuver and for pedestrians to evacuate safely. At higher road ranks, additional travel lanes and a 4m wide centered turn lane (in addition to the other lanes) can be added (see Fig. 3). Trees, shrubs, fences, and walls can be added in the area separating the buildings' edge and the walkways as protective barriers against shrapnel. Ramps for wheelchair users and those with mobility impairments should be provided at all intersections and building entrances.

Land use planning

Potential targets: Locating potential targets at a distance from site boundaries and easily identifiable landmarks can reduce their aerial recognizability during aerial attacks. Moreover, spacing targets apart can minimize the risk of multiple targets being affected by a single attack. Redundancy in critical infrastructure, such as public services, ensures continued functionality even if one facility is disrupted. Strengthening local service centers through decentralization and adopting unpredictable, polycentric distribution patterns can further enhance resilience (see Fig. 4). As for potentially explosive targets, locating them outside future cities and surrounding them with protective buffers is crucial to contain explosions and fires. The required distance from populated areas depends on the type of each explosive target and its blast radius.

Shelters: Establishing multi-purpose shelters beneath open spaces and neighborhood centers, in subway stations, underground stores, and similar locations, is crucial for civilian protection during attacks. To ensure adequate coverage and capacity, the quantity and quality of these shelters are recommended to meet specific criteria: the distance to the nearest shelter is advised not to exceed 650 meters (based on a 5-minute reach time at a running speed of 8 km/h), shelters are suggested to be no more than 1.3 kilometers apart, service areas are expected to overlap, and each shelter is required to provide at least 3.5 square meters of covered space per person (see Fig. 5).

Rescue services: Constructing healthcare and firefighting services within local service centers can play a vital role in facilitating rescue operations during attacks. These centers are recommended to be located no more than 5 kilometers apart, ensuring accessibility even under disrupted conditions.

Infrastructure planning

Placing all infrastructure networks and grids underground in future cities can enhance their defensive capabilities by reducing the risk of infrastructure failure during attacks. Additionally, integrating renewable energy systems into buildings, such as rooftop solar panels and micro wind turbines, is crucial for promoting energy decentralization, dispersing energy sources, and ensuring a continuous supply of power for essential needs. Furthermore, portable infrastructure solutions — including fuel-powered generators, hydropower units, and cell

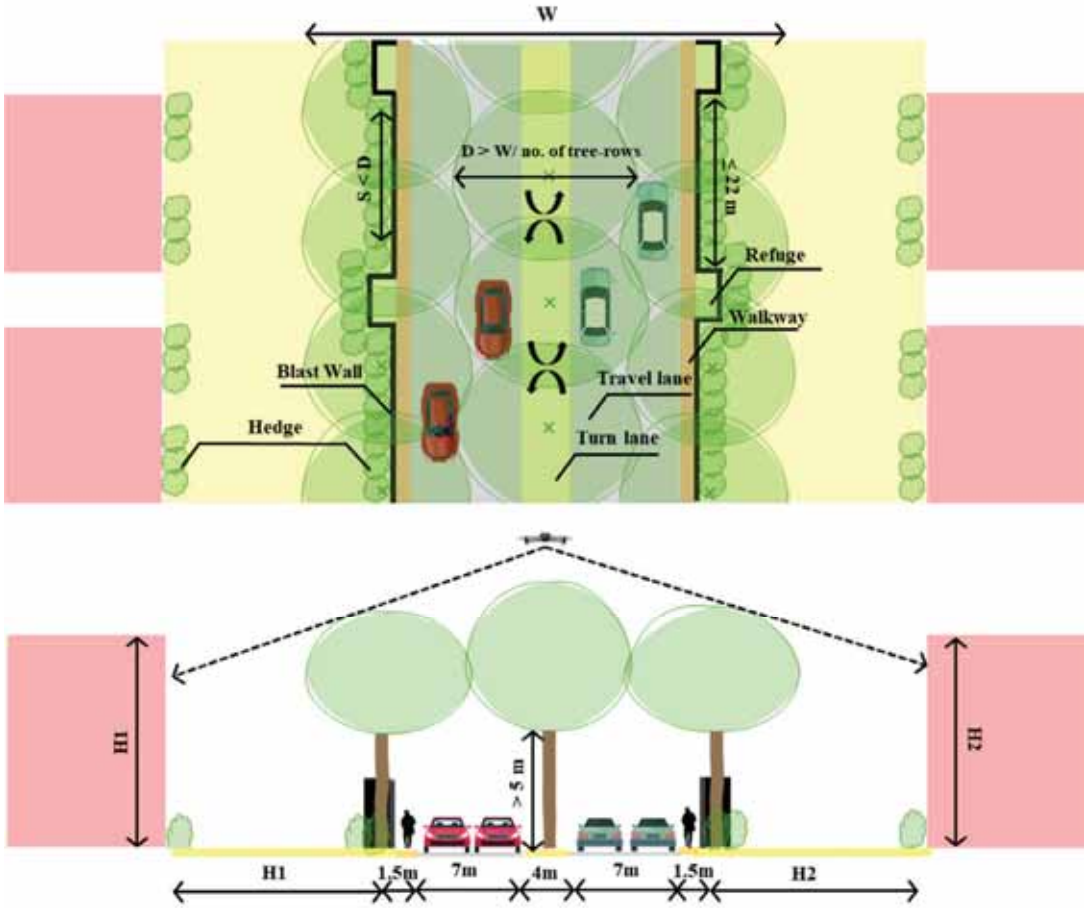
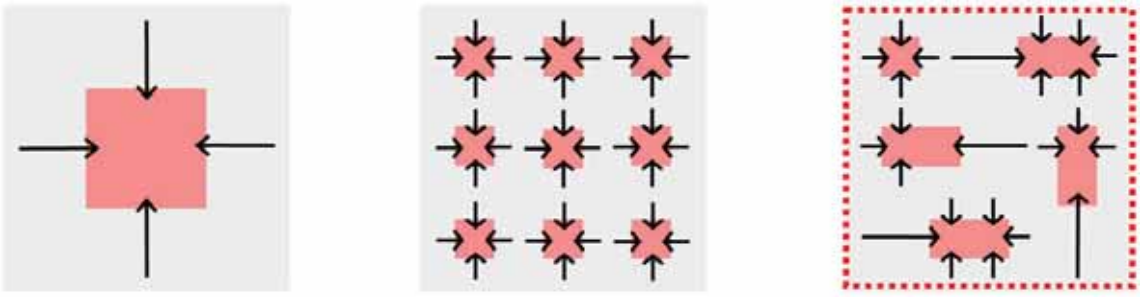


Fig. 3: Recommended street design for future cities



(a) (b) (c)

Fig. 4: Distribution of targets: (a) Centric Pattern, (b) Predictable Polycentric pattern, (c) Unpredictable Polycentric Pattern (recommended)

towers — can be deployed as emergency backups to maintain critical operations.

Urban design

Block configuration: Designing future cities with homogeneous block shapes and sizes can help integrate potential targets into the urban fabric, minimizing their contrast with surrounding structures and making them less identifiable from the air (see Fig. 6).

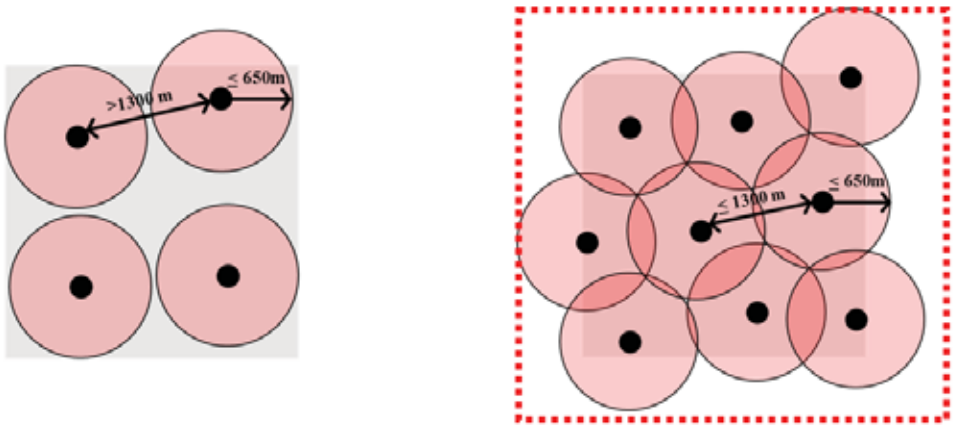


Fig. 5: Shelter's service area: (a) Separated, (b) Overlapped (recommended)

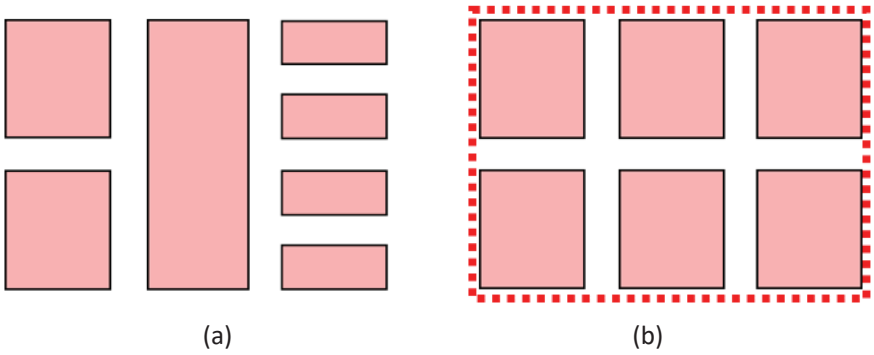


Fig. 6: Block configuration: (a) Heterogeneous sizes, (b) Homogeneous sizes (recommended)

Block length: Prioritizing short blocks, typically 150–200 meters, in future cities can help reduce the intensity of the blast wave while providing more navigation options for evacuation during attacks (see Fig. 7).

Building density: Adopting low building density in future cities can help create more open spaces and reduce population density, leading to increased options for evacuation and temporary shelter, and fewer casualties during attacks. While building density is an important metric, other factors, such as the spatial distribution of buildings and the distances between them, should also be considered to fully understand the concentration of structures on the site.

Building typology: Promoting point-building typologies in future cities can limit the spread of building damage, and influence blast wave propagation through deflection, potentially reducing the intensity of the blast impacting surrounding areas and enhancing their defensive capabilities (see Fig. 8).

Building arrangements: Encouraging in-line array building arrangements in future cities can create openings for explosions to expand into, potentially reducing the blast intensity but raising the risk of blast wave propagation and fire spread to surrounding areas during attacks. On the other hand, adopting staggered building arrangements can play a crucial role in reducing channeling winds and obstructing the direct path of blast waves. While this approach can help limit the spread of explosions and fires, it

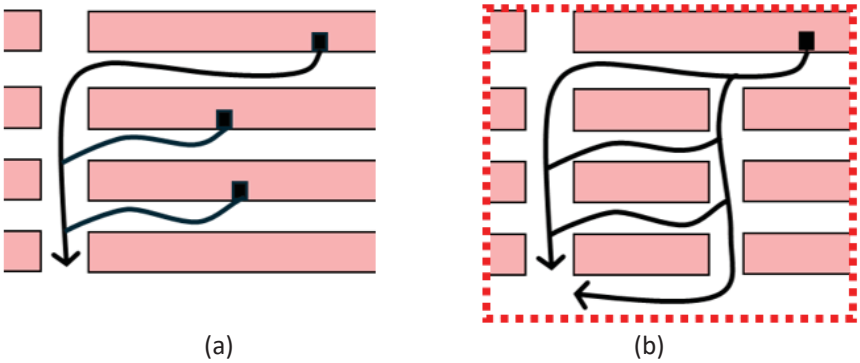


Fig. 7: Block length with navigation options: (a) Long blocks, (b) Short blocks (recommended)

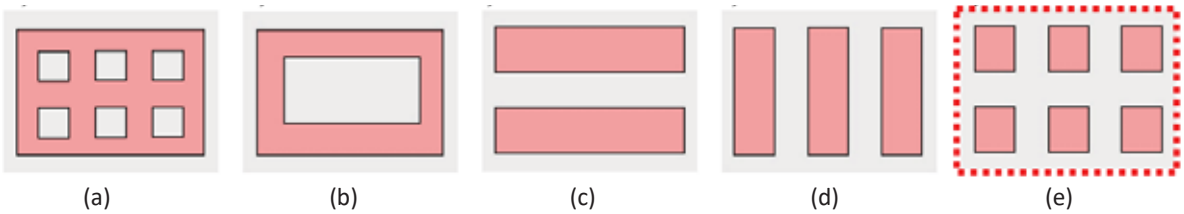


Fig. 8: Building typology: (a) Courtyard, (b) Closed, (c) Slab, (d) Barcode, (e) Point (recommended)

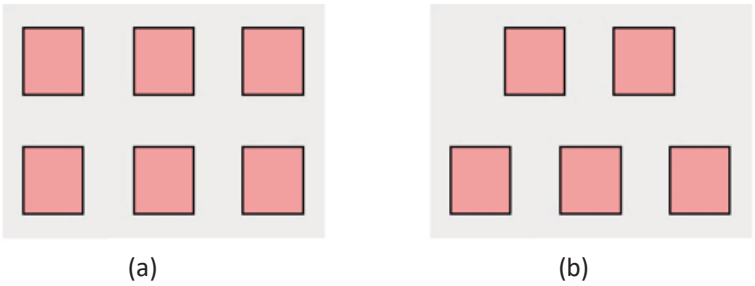


Fig. 9: Building arrangements: (a) In-line array, (b) Staggered

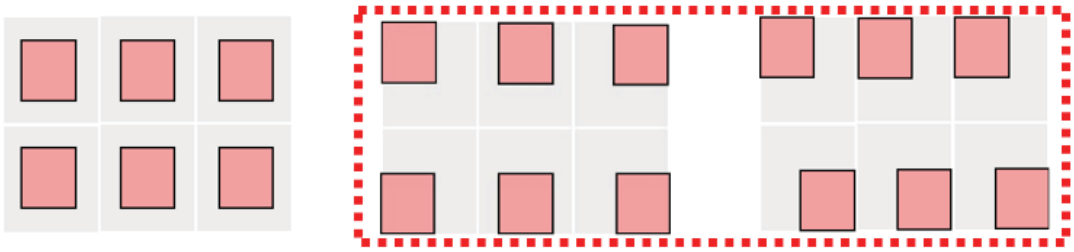
may also increase the blast intensity. Therefore, placing firebreaks between buildings is strongly recommended for in-line array arrangements, while enhancing the blast resistance of structures is essential for staggered arrangements (see Fig. 9).

Building position: Positioning buildings on opposite corners of building lots in future cities increases the space between them, helping to reduce the impact of explosions on the surrounding environment (see Fig. 10).

Open spaces: Designing open spaces (e.g., plazas, neighborhood parks, pocket parks, community gardens, and playgrounds) in future cities with dimensions exceeding the combined heights of the tallest buildings on either side can help protect these areas from debris, allowing them to serve as gathering points for evacuees, temporary shelters, and relief distribution centers (see Fig. 11). For smaller open spaces, adopting static shapes like squares and circles can enhance land use efficiency and minimize wasted space.

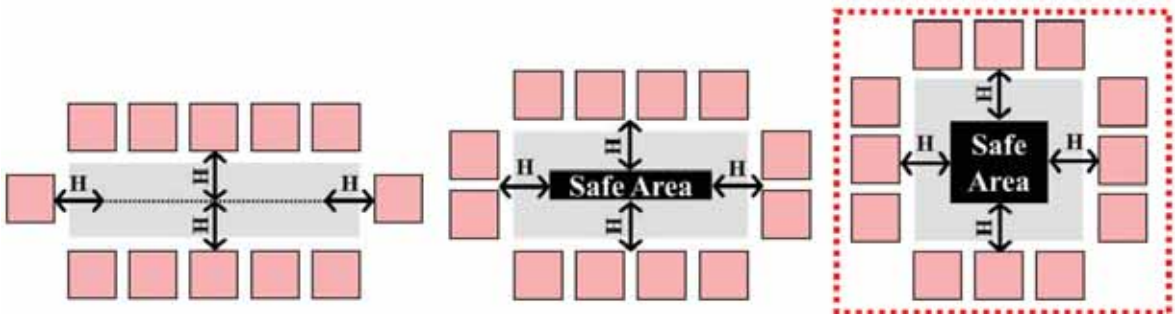
Landscape planning and design

Softscape elements: Adopting the following



(a) (b)

Fig. 10: Building position within lot: (a) Centered, (b) On opposite corners (recommended)



(a) (b)

Fig. 11: Shape of open space: (a) Dynamic shapes, (b) Static shape (recommended)

softscape practices in future cities is essential for concealing structures, obscuring their shadows, covering vehicular and pedestrian movements, and protecting buildings and people from shrapnel explosions, thereby strengthening their defense mechanisms during attacks (see Fig. 3):

• *Planting trees and shrubs at varied heights and irregular patterns around vulnerable structures and walkways.*

• *Selecting evergreen trees and shrubs with dense and large leaves for added coverage.*

• *To achieve the interlocking effect, the diameter of selected trees is recommended to be larger than the width of the space they cover, divided by the number of tree rows. Moreover, the spacing between trees when planting is suggested to be less than their diameter.*

• *The tree canopy is recommended to extend at least 5 meters above street level to maintain clear views and visual connectivity with the surroundings.*

Hardscape elements: Applying the following hardscape practices in future cities can be instrumental in mitigating building damage and limiting the spread of explosions and fires, reducing the risk of injury or death, and facilitating the evacuation process during wartime:

• *Construction of blast walls around vulnerable structures, walkways, and open spaces. The effectiveness of these walls depends on their height, thickness, and distance from the protected structures. Incorporating hedges into blast walls may enhance their effectiveness while also creating a more visually appealing landscape. Creating bends and breaks in blast walls can improve their resistance against blast waves and provide immediate refuges as well (see Fig. 3).*

• *Installation of hardened streetscape elements around walkways and within open spaces for protection against blast waves and flying debris. This may include benches, bins, planters, seat planters, and seat bollards. The nearest element is ideally reachable within 5 seconds. Given an average running speed of 8 km/h, the distance to the closest element is recommended to be around 11 meters. Therefore,*

the distance between different streetscape elements is suggested not to exceed 22 meters.

• *Placement of signage in strategic locations (e.g., intersections and crossings) to guide the evacuees to evacuation routes and assembly areas. The signage needs to be visible from a distance, durable, and resistant to potential damage.*

• *Adoption of non-slippery, textured, durable, and low-maintenance floor materials in open spaces and evacuation routes to prevent falls, enhance traction, withstand heavy foot traffic, and resist potential damage. Contrasting colors can be used to improve the visibility of evacuation routes and ensure they are easily identifiable.*

Architectural design

Building shape: Designing buildings in future cities to avoid closed and semi-closed (e.g., U-shaped or L-shaped) shapes and sharp corners can help mitigate the impact of shock waves and minimize potential building damage (see Fig. 12).

Building form: Prioritizing stepped or tapered building forms is recommended for future cities (see Fig. 13). This design reduces the overall amount of debris generated from building damage during attacks, minimizing the risk of injury or death. Minimizing building protrusions (e.g., overhangs, terraces, bay windows, porches, cornices, planter boxes, and air conditioner condenser units) can also contribute to a further reduction in the risk of falling debris.

Building height: Minimizing building height in future cities can help lower population density and reduce the number of vulnerable civilians. It also diminishes the vulnerability of buildings to aerial detection and decreases falling debris in case of being attacked. On the other hand, standardizing building height can aid in concealing potential targets. Therefore, it is recommended to unify building heights, keeping them low and restricted.

Structure system: Promoting blast-resistant structural systems in future cities can minimize

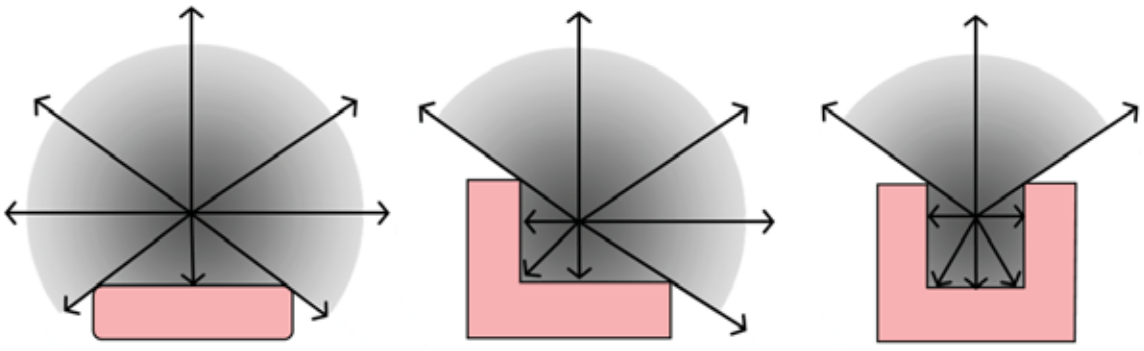


Fig. 12: Building shapes and their impact on blast waves: (a) Simple shape, (b) L-shape, (c) U-shape

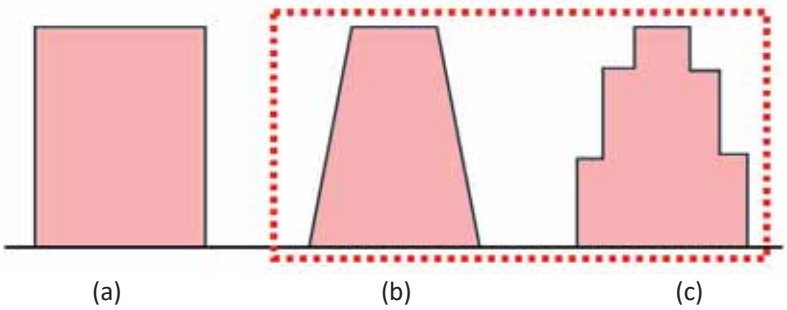


Fig. 13: Building form: (a) Regular, (b) Tapered, (c) Stepped (b and c are recommended)

building damage from explosions, thereby strengthening their overall defense. Composite steel and concrete systems are commonly used due to their combined strength and durability.

Basement design: Constructing buildings with centrally located basements, away from exterior walls, can provide safe shelters for civilians during attacks. Reinforcing the basement's walls and ceilings with additional structural elements, waterproofing the walls and floor, and installing ventilation systems to improve air quality help the basement withstand blast waves and debris, further enhancing safety. Additionally, ensuring at least two exits from the basement—one leading directly to the outside—can facilitate evacuation.

Cladding materials: Combining low-emissive and blast-resistant materials and coatings in buildings of future cities can create advanced defensive cladding systems that effectively mislead target tracking and reduce the damage in the event of an attack. In this regard, integrating low-emissive materials (e.g., carbon fiber panels) with blast-resistant coatings or combining blast-resistant materials (e.g., fiber-reinforced concrete) with radar-absorbing coatings is strongly recommended.

To ensure effective integration of the previous strategies into future cities, governments need to:

• Establish legal and regulatory frameworks to enforce passive defense strategies in buildings and cities, and incorporate mechanisms to monitor compliance with these regulations (e.g., mandating risk assessments before approving major construction projects).

• Strength coordination among planning, transportation, emergency management, law enforcement, and other relevant government agencies

• Update city planning codes to support redundancy and dispersal of critical infrastructure and services, resilient road networks, protected escape routes, buffer zones, underground infrastructure, multi-purpose underground shelters, reinforced public spaces, dense vegetation, hardened street furniture, and defensible urban layouts.

• Update building codes to incorporate blast-resistant designs, reinforced structures, designated shelters, safe underground rooms, and redundant utility systems.

• Require local governments to implement passive defense measures in all new constructions.

• Collaborate with private sector developers to incentivize the incorporation of passive defense measures into new developments.

• Secure dedicated funding by allocating a specific percentage of urban development budgets to passive defense initiatives.

• Encourage private sector participation through tax incentives, grants, and subsidies for developers who incorporate passive defense measures.

To elevate the effectiveness of these strategies, it is essential for governments to:

• Educate citizens about passive defense and encourage civic participation in emergency planning.

• Promote community preparedness through training programs, emergency drills, and neighborhood watch groups, fostering a culture of resilience and proactive safety.

• Establish effective communication channels with residents to provide timely and accurate information during emergencies and gather feedback on the effectiveness of passive defense measures.

• Deploy AI-powered systems to enhance real-time situational awareness, predict and identify potential threats and vulnerabilities, and issue timely alerts and warnings to residents in affected areas. These systems can also dynamically optimize evacuation routes and emergency response plans based on live data, such as traffic congestion, road closures, and shelter availability, ensuring swift and efficient crisis management.

These strategies provide a multi-dimensional approach to empowering governments in developing future cities that are safer, more resilient, and capable of withstanding and adapting to emerging attacks—while prioritizing the well-being of their residents.

CONCLUSION

This study investigated the critical role of urban planning and design in enhancing the passive defense capabilities of future cities during wartime. In this context, the Russia-Ukraine and Israel-Palestine conflicts were analyzed to recognize the common behavior of attack and investigate the characteristics of targets. It was found that the dominant military action in attacking strategic targets is air and artillery strikes, which depend heavily on aerial detection of potential targets. Accordingly, passive defense strategies and measures to protect targets from aerial

detection and minimize the damage in case of being attacked were reviewed. Based on these measures, planning and design criteria were developed and planning components fulfilling these criteria were identified. It was found that site selection, population density, urban network planning (including network pattern, street shape, street openings, and street design), land use planning of potential targets, shelters and rescue services, infrastructure planning, urban design (including block configuration, block length, building density, building typology, building arrangements, building position, and open spaces shape), landscape planning (including softscape and hardscape elements), and architectural design (including building shape, form, and height, structure systems, basement design, and cladding materials) can play an important role in enhancing passive defense capabilities of future cities during wartime. Finally, planning and design strategies were developed to enhance the passive defense capabilities of future cities, based on these components. These include prioritizing naturally protected sites, maintaining low population density, utilizing multiple network patterns and street shapes with T-junctions, implementing an unpredictable polycentric distribution of targets, integrating renewable energy and portable infrastructure solutions, designing homogeneous short blocks with low building density and point-building typology, incorporating low-rise stepped or tapered buildings with rounded corners, centering basements, employing blast-resistant structural systems, and using low-emissive, blast-resistant materials and coatings. It is worth noting that this study introduces conceptual strategies. Thus, further research is needed to evaluate the effectiveness of these strategies across diverse urban contexts. Additionally, it is crucial to explore how these strategies can be integrated without compromising livability, ensuring that security enhancements do not lead to an over-militarized or restrictive urban environment.

AUTHOR CONTRIBUTIONS

The author performed the conception and design of the work, data collection, data analysis, methodology, article drafting, editing, and writing.

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CONFLICT OF INTEREST

The author declares no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

BTS	Base Transceiver Stations

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ORIGINAL RESEARCH PAPER

Factors influencing employees' intentions to adopt blockchain technology in accounting information systems in local government

H. Sofyani[1*], H. Abu Hasan[2], A. Idris[3]

[1]*Department of Accounting, Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta, Bantul, Indonesia*

[2]*Department of Accounting, Faculty of Business and Economics, Universiti Malaya, Kuala Lumpur, Malaysia*

[3]*Department of Management and Marketing, Faculty of Business and Economics, Universiti Malaya, Kuala Lumpur, Malaysia*

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ABSTRACT

BACKGROUND AND OBJECTIVES: The development of blockchain and the benefits it promises to enhance accountability have led many countries to adopt it in their e-government. The motivation for this study was the lack of studies examining the adoption factors of blockchain in the accounting information system in local governments. Explicitly, this study investigated employees' intentions to adopt blockchain technology within the AIS of Indonesian Local Government Units by combining the Technology Acceptance Model and the Unified Theory of Acceptance and Use of Technology as theoretical frameworks.

METHODS: The research used a survey approach and focused on Local Government Units in the Yogyakarta Special Region Province. The respondents were employees using accounting software. The data were analyzed using the Partial Least Squares method.

FINDINGS: The results indicated that facilitating conditions, trust, and performance expectancy positively influenced the perceived ease of use and perceived usefulness of blockchain technology. Specifically, trust had a strong positive effect on both ease of use ($\beta = 0.424$, $p < 0.01$) and perceived usefulness ($\beta = 0.364$, $p < 0.01$), while performance expectancy strongly influenced perceived usefulness ($\beta = 0.429$, $p < 0.01$). Facilitating conditions were found to impact ease of use significantly ($\beta = 0.220$, $p < 0.01$) but not perceived usefulness ($\beta = 0.044$, $p > 0.05$). Regarding employees' intention to adopt blockchain, ease of use positively influenced the intention ($\beta = 0.168$, $p < 0.05$), while perceived usefulness did not ($\beta = 0.093$, $p > 0.05$). Mediation analysis revealed that ease of use partially mediated the relationship between trust and intention to adopt (indirect effect = 0.050, $p < 0.05$) and fully mediated the relationship between performance expectancy and intention to adopt (indirect effect $\beta = 0.071$, $p < 0.05$). Conversely, perceived usefulness did not mediate the adoption intention (indirect effects $\beta = 0.004$, 0.040, and 0.034, respectively, $p > 0.05$).

CONCLUSION: These findings provided valuable insights for policymakers and local leaders in enhancing adoption strategies for blockchain technology in local government's AIS, particularly by focusing on trust, ease of use, and performance expectancy.

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37	2	7

*Corresponding Author:
Email: *hafiez.sofyani@umy.ac.id*
Phone: 085725791411
ORCID: 0000-0003-3077-9097

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INTRODUCTION

Blockchain is considered one of the most significant and possibly disruptive technologies of the 21st century (Falwadiya and Dhingra, 2022). Fig. 1 illustrates various applications and cases for blockchain technology, highlighting its potential for implementation across different areas, including accounting information systems.

Due to its potential benefits, blockchain technology has been implemented across several countries in their public sector. According to Jun (2018), numerous countries are leveraging blockchain technology to improve their e-government services, for example, Australia, China, Estonia, France, Ghana, Georgia, Honduras, Kazakhstan, Sweden, Switzerland, Ukraine, and the UK. A global survey revealed that 87% of senior executives believe blockchain will further enhance integration in touchless business processes, while 86% see it unlocking new business opportunities and revenue streams (Deloitte, 2019). Additionally, 83% of organizations expressed confidence in meeting financial reporting requirements related to blockchain (Deloitte, 2020). In addition, some empirical studies support the benefits brought by blockchain technology. Khan *et al.,* (2022) pointed out that the Dubai government has adopted blockchain technology to make its public services more efficient and effective, allowing for a smoother and more accountable governance framework. Larikova *et al.,* (2023) discussed the application of blockchain technology in public sector accounting, which can be used to establish a smart contract system to improve financial reporting and budget execution. Sung and Park

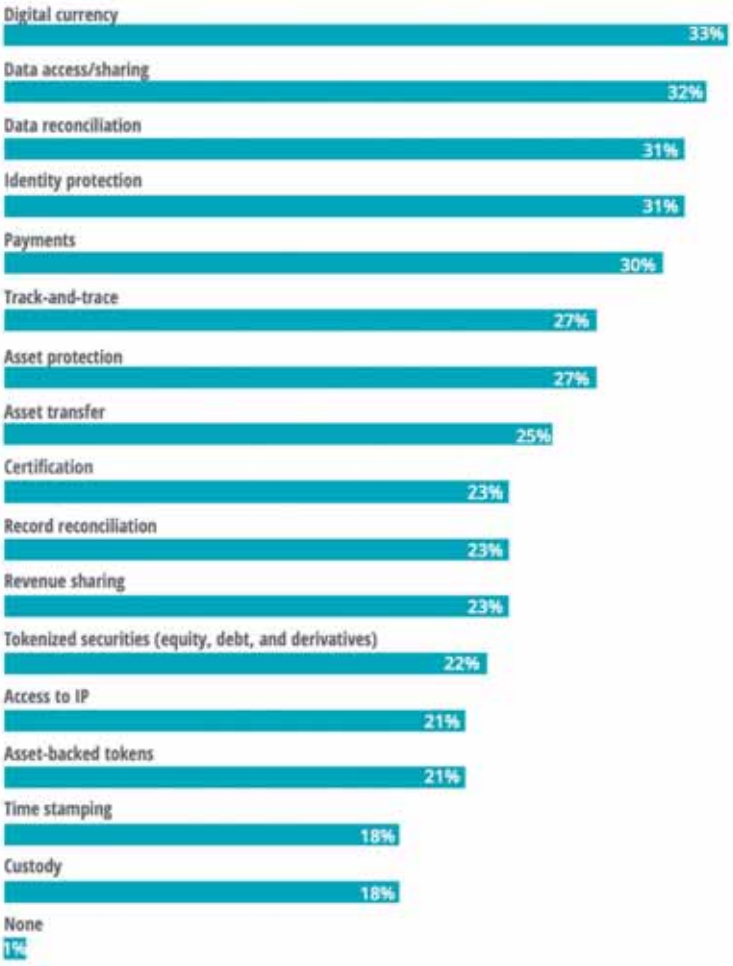

Fig. 1: The Use Cases for Blockchain Technology (source: Deloitte, 2020)

(2021) emphasized that blockchain can significantly improve transparency, accountability, and reliability in user data control while reducing costs and increasing administrative efficiency in public service delivery. However, in the earlier stages of adopting blockchain into the public sector, many countries faced significant apprehensions about the practical implementation of this technology. Most of these apprehensions were related to security and privacy since there was some doubt about how blockchain could protect the sensitive data of governments from cyber threats (Belonick, 2020). For instance, Estonia was able to integrate blockchain technology into its e-governance system primarily due to the necessity of building resilient infrastructures to counter cyber threats, particularly following significant cyberattacks in 2007 (Semenzin *et al.*, 2022). Other countries encountered high regulatory uncertainties and substantial infrastructure changes, which hindered blockchain adoption. According to Pirrong (2019), high implementation costs and technical challenges to integration with existing systems have made blockchain technology more difficult to understand and adopt. This indicates that facilitating conditions must be in place, and there is a concern for the smooth adoption of blockchain technology. In addition, Ramos and Queiroz (2022) argued that trust in new technology significantly affects blockchain adoption in academic institutions due to the benefits, such as secure data sharing and transaction transparency, which optimize daily routines and prevent fraud in academic documents. Despite these advancements, trust-related challenges like costs and privacy must be addressed (Tan and Saraniemi, 2023). The findings of the above studies conclude that blockchain adoption needs to consider the importance of facilitating conditions, the performance that blockchain technology will bring, and the trust of potential users. However, according to a survey, while 88% of senior executives believe blockchain will achieve mainstream adoption, only 39% have implemented it within their organizations (Gilbert, 2024). Since 2019, the Indonesian government has been exploring the possibility of incorporating blockchain technology into its e-government plans, particularly in accounting. This initiative aims to enhance operational efficiency, transparency, and public engagement across government systems (Sofyani, 2024). The potential of blockchain in preventing corruption has been explored, particularly when combined with forensic accounting practices, to create a strong tool against corruption in the country (Oladejo and Jack, 2020). The consideration of the Indonesian government toward blockchain development for e-government is a strategic step to modernize governance practices and to enhance service delivery and accountability (Andaru and Utami, 2024). However, despite the potential of blockchain technology to address these needs, there is a notable lack of comprehensive research on the readiness for blockchain adoption in the public sector's accounting information system (AIS), especially in developing countries. To fill these gaps, this study aims to determine Indonesian local governments' intention to adopt blockchain technology in their AIS. Specifically, this study tests two factors from the Technology Acceptance Model (TAM), including perceived ease of use and perceived usefulness, and three from the Unified Theory of Acceptance and Use of Technology (UTAUT), such as trust, facilitating conditions, and performance expectancy. The theoretical model of this study is presented in Fig. 2. This research adds to the current theoretical understanding of blockchain adoption by integrating the TAM and the UTAUT Models. These models are extended to the specific context of Indonesian local governments, thereby broadening the applicability of this research to the public sector in developing countries. Although this study is a form of replication, it is important to carry out, as replication research plays a key role in assessing the reliability of previous findings and supporting the development of empirical generalizations based on the outcomes of the original study (Anderson and Maxwell, 2017). In addition, this research will provide practical guidance to Indonesian policymakers and government officials on how blockchain technology can be successfully integrated into AIS. It also establishes a benchmark for future e-government initiatives involving blockchain technology by providing an in-depth review of the current adoption readiness to guide subsequent projects. Moreover, it will also assist the related ministries in preparing for the integration of blockchain technology in Indonesia. The research survey was conducted in Local Government Units in the Yogyakarta Special Region province, Indonesia, in 2023.

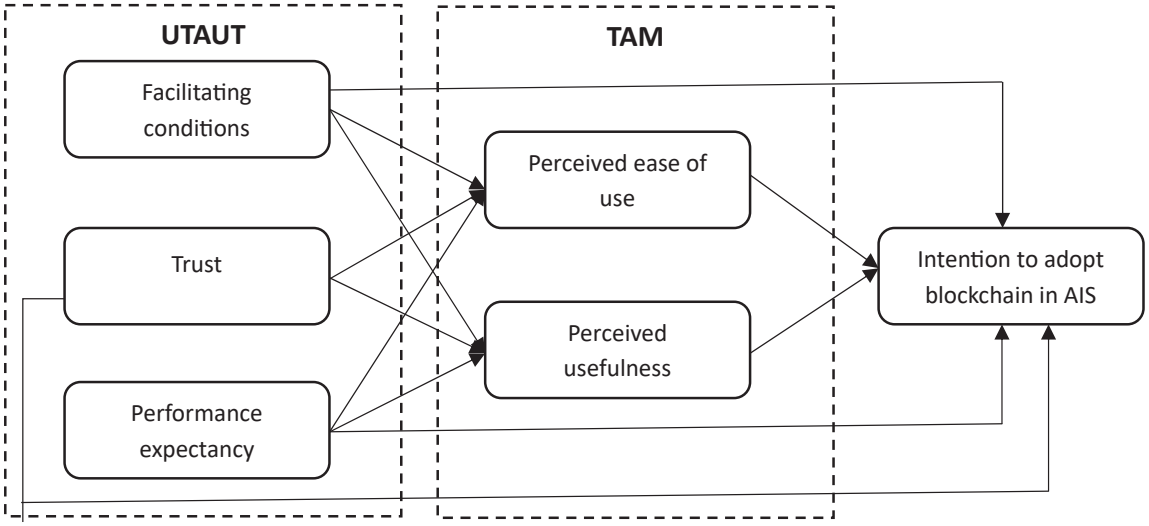

Fig. 2: Proposed theoretical framework

MATERIALS AND METHODS

The study population comprised all employees working in the Local Government Units (LGUs) in Yogyakarta Special Region Province, Indonesia. This study adopted purposive sampling, explicitly targeting employees involved in financial administration and accounting applications. This study also utilised primary data and used a questionnaire as an instrument for data collection. According to Memon (2020), researchers must calculate the sample size using power analysis. Power analysis is a method used to calculate the minimum number of samples that can be used for a study. Power analysis was conducted using G*Power software in this study. The results indicated that the minimum sample size should be 92 employees. A total of 663 questionnaires were distributed, out of which 295 or 45% could be processed. This number has fulfilled the minimum sample requirement. Before starting the study, the research proposal was submitted to the Research Ethics Committee at the university where the first author is affiliated. The proposal was approved for implementation after several revisions were made based on the committee's feedback. The committee's notes highlighted a few essential requirements, including obtaining permissions, providing a consent form, ensuring the confidentiality and safety of participants, and protecting them from any potential risks associated with their involvement in the study. The questionnaire was distributed during September and October 2023. Before data collection, the questionnaire was reviewed and tested by experts with backgrounds in public-sector accounting and AIS (Lewis *et al.*, 2005). Table 1 presents the operational definition and measurement of each variable. Then, the questionnaires were distributed by presenting a research permit issued by the relevant authority. The questionnaire, along with the permit, was directly distributed to the employees of the LGUs in their offices to ensure a high response rate and alignment with respondent criteria. The data analysis used Partial Least Squares (PLS) with the SmartPLS version 4.0 software. PLS-SEM was used in this study due to the exploratory nature of the research. This data analysis technique validates or refutes previous research results or theories (Hair Jr *et al.*, 2014). The stages of data analysis encompass several tests and analyses, including the Common Method Variance (CMV) test, descriptive statistical analysis, convergent validity test, discriminant validity test, reliability test, R^2 test, hypothesis testing, and prediction test.

RESULTS AND DISCUSSION

The survey data includes a diverse group of respondents with several notable characteristics. Table 2 depicts the information on the characteristics of respondents. Regarding gender, women constitute most of the respondents at 55.59%. The largest age group is 20-35, representing 42.71% of the sample. The sample interestingly includes high school

Table 1: Operational definition of variables

Variable	Definition	Instrument sources
Intention to adopt	An organization's positive or negative perception of technology influences its decision.	Hashimy *et al.,* (2023)
Perceived usefulness	The degree to which individuals believe that using the technology will enhance their performance	McNamara *et al.,* (2024)
Perceived ease of use	The extent to which users perceive the technology as easy or uncomplicated to use.	Kabir (2021)
Facilitating condition	The belief is that organizational and technical infrastructure exists to support system use.	Venkatesh *et al.,* (2003)
Trust	Users' confidence in the system's reliability and security.	Greenberg *et al.,* (2012)
Performance expectancy	The degree to which an individual perceives that using the system will help improve job performance.	Venkatesh *et al.* (2003)

Table 2: Characteristics of respondents

Criteria	Description	Total	Frequency (%)
Gender	Number of Respondents	295	100.00
	Male	88	29.83
	Female	164	55.59
	Not mentioned	43	14.57
Age	Number of Respondents	295	100.00
	20-35 years	126	42.71
	36-50 years	93	31.52
	>50 years	31	10.50
	Not mentioned	45	15.25
Education level	Number of Respondents	295	100.00
	High School	50	16.94
	Diploma 1/diploma 2	1	0.33
	Diploma 3/bachelor	216	73.22
	Master	23	7.79
	Not mentioned	5	1.69
Educational background	Number of Respondents	295	100.00
	Accounting	132	44.74
	Management	41	13.89
	Economy	21	7.11
	Others	68	23.05
	Not mentioned	33	11.18

students, making up 16.94%, while most respondents hold a Diploma 3 or bachelor's degree (73.22%). Accounting is the most common educational background, with 44.74% of respondents indicating it. Including various age groups, education levels, and backgrounds suggests a comprehensive and representative sample.

Before analyzing the data, the Harman single-factor test was used to detect the presence of Common Method Bias (CMB), which is critical for self-reported survey data. CMB can be problematic when a single latent component accounts for most of the explained variance or the score exceeds 50% (Podsakoff *et al.*, 2003). The test result showed that the first component accounted for only 37.57% of the variance, indicating an insignificant impact on the result findings (Podsakoff *et al.*, 2003). The descriptive statistics in Table 3 reveal that employees in Indonesian LGUs generally perceive blockchain technology as useful (mean = 3.73) and moderately easy to use (mean = 3.66), with trust (mean = 3.60) and performance expectancy (mean = 3.62) also

Table 3: Descriptive statistics

Variables	Minimum	Maximum	Mean	Std. deviation
Facilitating conditions	1.00	5.00	3.09	0.76
Trust	2.00	5.00	3.60	0.67
Performance expectancy	2.00	5.00	3.62	0.62
Perceived ease of use	1.00	5.00	3.66	0.65
Perceived usefulness	1.00	5.00	3.73	0.66
Intention to adopt	1.00	5.00	3.64	0.68

Table 4: Loading (convergent validity)

Codes	Outer loading	AVE
Intention to adopt		
ITU1	0.816	0.731
ITU2	0.829	
ITU3	0.891	
ITU4	0.882	
Perceived ease of use		
PEOU 1	0.862	0.758
PEOU 2	0.860	
PEOU 3	0.890	
PEOU 4	0.869	
Perceived usefulness		
PU1	0.861	0.846
PU2	0.917	
PU3	0.944	
PU4	0.954	
Facilitating conditions		
FC1	0.818	0.688
FC2	0.833	
FC3	0.814	
FC4	0.852	
Trust		
T1	0.885	0.737
T2	0.911	
T3	0.774	
Performance expectancy		
PE1	0.901	0.823
PE2	0.930	
PE3	0.891	

rated positively. However, facilitating conditions are perceived somewhat less favourably (mean = 3.09), indicating that support and infrastructure for adoption may need improvement. The intention to adopt blockchain is moderate (mean = 3.64), with variability in responses suggesting that while many employees are open to adoption, some remain hesitant. These findings highlight the need for targeted efforts to enhance trust, ease of use, and supporting conditions to facilitate successful blockchain adoption in AIS.

As a general guideline, a threshold of 0.5 was applied for loadings and cross-loadings assessments (Hair *et al.*, 2022). In the evaluation, all items achieved satisfactory loading and Average Variance Extracted (AVE) scores (Table 4), theoretically indicating that the existing indicators effectively measured the intended constructs, thereby demonstrating convergent validity (Hair *et al.*, 2022).

A discriminant validity test was conducted to determine the validity of the data by analyzing the correlations between measurements of potentially overlapping constructs. From Table 5, the correlation scores between internal constructs (the root of AVE) were higher than those between external constructs (Gefen and Straub, 2005). This confirms that discriminant validity was successfully achieved (Hair *et al.*, 2022).

Next, inter-item consistency was measured using

Table 5: Discriminant validity test result using the Fornell-Larcker method

Constructs	1	2	3	4	5	6
Ease of use	0.870					
Facilitating condition	0.619	0.829				
Intention to adopt	0.625	0.601	0.855			
Performance expectancy	0.681	0.536	0.521	0.907		
Trust	0.734	0.561	0.617	0.623	0.859	
Usefulness	0.747	0.479	0.547	0.680	0.657	0.920

Table 6: The results of the construct reliability test

Constructs	Cronbach's alpha	Composite reliability
Ease of use	0.894	0.926
Facilitating condition	0.849	0.898
Intention to adopt	0.877	0.916
Performance expectancy	0.893	0.933
Trust	0.819	0.893
Usefulness	0.939	0.956

Cronbach's alpha and composite reliability scores, as shown in Table 6. The results revealed that all alpha scores were above 0.6, considered reliable according to (Chin *et al.*, 2003). Additionally, composite reliability levels of 0.70 or higher, deemed acceptable by (Fornell and Larcker, 1981), were also achieved. Therefore, the scores obtained in this study were considered reliable.

Since the validity and reliability tests are fulfilled, the data can be used to test the hypothesis through structural model assessment, and the results are presented in Table 7. The adjusted R^2 for the research model is moderate at 0.464, meaning that the exogenous variables account for 46.4% of the variation in the endogenous variable (intention to adopt), with the remaining variation explained by factors not included in the model (Chin, 1998). Additionally, although model fit is not the primary focus of PLS analysis, it is often assessed. In this case, the SRMR value is below 0.10, indicating that the model demonstrates a good fit (Hair Jr *et al.*, 2022).

Note: adjusted R^2 = 0.464; SRMR = 0.084; * $p < 0.05$; ** $p < 0.01$

Discussions

Consistent with prior research (Venkatesh *et al.*, 2003; Hair *et al.*, 2019), this study finds that facilitating conditions significantly impact ease of use and intention to adopt, but not Usefulness. This indicates that while external conditions enhance system usability and adoption, they do not necessarily influence users' perceptions of the system's practical value. A new insight from this study is that local governments must not only focus on improving support infrastructure for ease of use but also must demonstrate the system's practical benefits to enhance its perceived usefulness, which has not been emphasized as strongly in previous studies. The study also identifies Trust as a key predictor of Ease of Use, Usefulness, and Intention to adopt, aligning with established findings on technology acceptance (Chan *et al.*, 2021; Chawla and Joshi, 2023). An important novel finding is the significant role of trust in directly influencing users' perceptions of both ease of use and usefulness, further boosting their intention to adopt the technology (Okello Candiya Bongomin and Ntayi, 2020). This finding highlights that trust is not merely a supporting factor but a critical enabler in blockchain adoption, which has been underexplored in the specific context of blockchain in local government settings. Given the central role of trust, local governments must prioritize building transparency, implementing robust security measures, and ensuring consistent system performance to foster user confidence. In contrast, Performance Expectancy shows mixed results. While it influences both ease of use and usefulness, it does not significantly impact Intention to adopt. The novel insight here is that, while users may expect systems to be both simple and useful, these factors alone are not sufficient to drive adoption intentions. This suggests that additional motivational factors or incentives may be necessary, which has not been widely considered in previous

Table 7: The results of the structural model assessment

Relationship	Dependent variables		
	Perceived Ease of Use	Perceived Usefulness	Intention to adopt
Direct effects			
Facilitating conditions	0.220** (H_{1a} Supported)	0.044 (H_{1b} Unsupported)	
Trust	0.424** (H_{2a} Supported)	0.364** (H_{2a} Supported)	
Performance expectancy	0.299** (H_{3a} Supported)	0.429** (H_{3a} Supported)	
Facilitating conditions			0.305**
Trust			0.245**
Performance expectancy			0.026
Perceived Ease of Use			0.168* (H_4 Supported)
Perceived Usefulness			0.093 (H_5 Unsupported)
Indirect effects (Mediation)			
Facilitating Conditions → Perceived Ease of Use			0.037 (H_{6a} Unsupported)
Facilitating conditions → Perceived Usefulness			0.004 (H_{6b} Unsupported)
Trust → Perceived Ease of Use			0.050* (H_{6c} Partial Mediation)
Trust → Perceived usefulness			0.040 (H_{7a} Unsupported)
Performance expectancy → Perceived Ease of use			0.071* (H_{7b} Full Mediation)
Performance expectancy → Perceived Usefulness			0.034 (H_{7c} Unsupported)

models of adoption where Performance Expectancy is often seen as a major determinant (Zhou *et al*., 2021). Moreover, the mediation analysis reveals that ease of use is a stronger mediator than usefulness, which is an important and novel contribution. This finding aligns with the context of blockchain adoption in local governments, where initial concerns often centered on usability rather than utility (David *et al*., 2023). A key new insight is that early-stage users prioritize ease of navigation and system usability over its utility, which directly influences their intention to adopt. The mediation analysis also clarifies that Performance Expectancy influences adoption intention only through ease of use, reinforcing the idea that for local government employees, ease of use remains the primary determinant for blockchain-based AIS adoption, a critical insight for guiding future implementation strategies.

Theoretical implications

This study offers theoretical contributions by integrating the Technology Acceptance Model (TAM) (Davis, 1989) and the UTAUT (Venkatesh *et al*., 2003) frameworks to examine blockchain-based AIS adoption, particularly in the public sector. TAM, which emphasizes perceived ease of use and perceived usefulness as key determinants of technology adoption, has been widely applied in prior research (Chen and Aklikokou, 2020; Davis, 1989; Venkatesh *et al*., 2003). Our findings support TAM's emphasis on perceived ease of use but suggest that only ease of use emerged as a critical driver of adoption, while usefulness played a secondary role. Trust and facilitating conditions significantly impacted both ease of use and adoption intention, aligning with research highlighting the importance of trust in technology adoption (Adnan *et al*., 2018). However, TAM alone does not fully capture the role of external factors in influencing adoption decisions. UTAUT extends TAM by incorporating external influences such as facilitating conditions, performance expectancy, and trust, providing a

more comprehensive framework for understanding technology adoption (Venkatesh *et al*., 2012). The significance of facilitating conditions in this study aligns with prior studies, which emphasize the role of external infrastructure, support mechanisms, and institutional readiness in enabling ease of use and adoption (Oliveira *et al*., 2016). By integrating TAM and UTAUT, this study contributes to a more holistic understanding of blockchain-based AIS adoption by capturing both internal user perceptions and external environmental factors.

Practical implications

The results of this study offer actionable insights for policymakers and organizations seeking to improve blockchain-based AIS adoption. First, local governments should prioritize improving system usability, as ease of use is a key driver of both trust and performance expectancy (Davis, 1989; Venkatesh *et al*., 2003). Prior research has shown that user-friendly system designs and intuitive interfaces can enhance perceived ease of use and adoption rates (Venkatesh *et al*., 2012). Providing comprehensive training, tutorials, and workshops can further strengthen user confidence in blockchain-based AIS (Saadati *et al*., 2023). Facilitating conditions—such as technical support, user manuals, and responsive customer service—are critical in improving perceived ease of use and fostering adoption (Farinloye *et al*., 2024). Studies suggest that adequate institutional and technical support reduces adoption barriers and encourages sustained technology use (Dwivedi *et al*., 2019). Building trust in blockchain-based AIS is another crucial factor influencing adoption (Gökalp *et al*., 2022). Trust has been shown to significantly shape perceptions towards ease of use, usefulness, and adoption intention in digital systems (Zubir and Abdul Latip, 2024). Governments can cultivate trust by ensuring data security, system reliability, and transparency in system performance (Janssen *et al*., 2020). Regular updates, clear communication, and visible security features—such as cryptographic assurances and immutable ledgers—can enhance trust and encourage wider adoption (Saberi *et al*., 2019). By focusing on these key areas, organizations and policymakers can facilitate blockchain-based AIS adoption, leading to more efficient and transparent financial management in the public sector.

CONCLUSION

This research explores the intention of Indonesian local government employees to adopt blockchain technology in AIS. The analysis revealed key relationships between variables influencing blockchain adoption. Facilitating conditions, trust, and performance expectancy positively impacted perceived ease of use, while trust and performance expectancy also positively affected perceived usefulness. However, facilitating conditions did not have a significant impact on usefulness. Importantly, facilitating conditions and trust directly influenced the intention to adopt, while performance expectancy did not. Perceived ease of use was a critical factor, significantly influencing adoption intention, while perceived usefulness had no significant effect. Mediation analysis revealed that ease of use served as a mediator for the effects of trust and performance expectancy on adoption intention, but it did not mediate the relationship between facilitating conditions and adoption intention. Furthermore, perceived usefulness did not mediate any relationships. These findings underscore the importance of focusing on variables that improve ease of use and build trust in promoting blockchain adoption among the local government AIS settings.

AUTHOR CONTRIBUTIONS

H. Sofyani actively wrote the manuscript and carried out data processing and interpretation. H. Abu Hasan and A. Idris contributed to writing, interpreted the data, and conducted proofreading.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. This study adhered to ethical principles, including preventing plagiarism, obtaining informed consent, addressing misconduct, avoiding data fabrication or falsification, preventing double publication, and avoiding redundancy.

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ABBREVIATIONS (NOMENCLATURE)

R^2	Coefficient of determination
AIS	Accounting Information System
AVE	Average Variance Extracted
BCT	Blockchain Technology
CMB	Common Method Bias
CMV	Common Method Variance
LGUs	Local Government Units
LM	Linear Regression Model
MAE	Mean Absolute Error
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
p	Probability value
PLS	Partial Least Squares
RMSE	Root Mean Square Error
SD	Standard Deviation
SRMR	Root Mean Square Residual
β	Coefficient

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ORIGINAL RESEARCH PAPER

Strategic performance management in the municipality through dynamic balanced scorecard and game theory

S.H. Seyedi[1,*], A. Yousefi Hanoomarvar[2]

[1]*Department of Industrial Engineering and Management, Shahrood University of Technology, Shahrood, Iran*

[2]*Department of Humanities and Social Sciences, Ardakan University, Ardakan, Iran*

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ABSTRACT

BACKGROUND AND OBJECTIVES: Aligning short and long-term goals, operational plans, and vision, the interests of the organization's internal and external stakeholders, and investing in intangible and late-returning assets are the characteristics of a strategic performance management system. The importance of strategic performance management for public organizations such as municipalities increases due to its direct impact on the quality of life of the urban community. The balanced scorecard is one of the most used tools in this field, which, along with its operational advantages, also has important weaknesses. This study aims to explore the application of a dynamic balanced scorecard framework integrated with game theory to enhance strategic performance management in the municipality.

METHODS: In this paper, the system dynamics is used to design the dynamic strategy map of the Tehran Region 4 municipality with a case study approach. After designing performance improvement strategies, the strategies are simulated, and the best combination of strategies is selected with a cooperative game theory approach.

FINDINGS: The results revealed that the customer's perspective and the learning and growth perspective have the highest Shapley values of 5.38 and 4.64, respectively. Therefore, in choosing the best strategies for the municipality, attention should be paid to the strategies that improve these two perspectives. Based on this, the combination of strategies $C_1L_1I_1F_1$, $C_2L_2I_3F_3$, and $C_3L_3I_2F_2$ is selected.

CONCLUSION: Simulating KPIs and examining scenarios lead to a better understanding of the factors influencing the organization's success and preventing bias in strategic decisions. Also, a suitable mechanism for strategy selection creates a better agreement between managers for sympathetic implementation. This paper presented a framework for strategic performance management by combining dynamic BSC and game theory, and the effectiveness of the framework is investigated by conducting a case study in the municipality.

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*Corresponding Author:
Email: *sh.seyedi@shahroodut.ac.ir*
Phone: +98(23)32391539
ORCID: 0000-0002-9438-9082

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INTRODUCTION

Management of any organization without performance assessment measurement tools is akin to navigating a ship without navigational instruments. To establish an effective performance evaluation system, criteria must be chosen that best reflect and indicate the organization's strategies. Strategy is about the long-term vision of the organization, which is in the form of a plan, ploy, pattern, perspective, or situation about the organization's intentions (Mintzberg 1994). The past two decades have witnessed a sharp increase in global business competition fueled by fast technological evolution and product diversification (Wardhana, Musa, Kurniawan, 2023). This climate has increased the necessity of continuous performance improvement as a strategic tool, and businesses are forced to use strategic indicators to improve their organizational performance and competitive advantage (Zighan, and Ruel, 2023; Huang *et al.*, 2011). Today, enterprises and organizations have to use a wide range of performance measures to assess, control, and improve their business processes to maintain and enhance their competitive advantage. (Cagno *et al.*, 2023). Performance evaluation is not about the past; it is about the future (Yadav, 2020). Performance evaluation benefits organizations in a variety of ways. Most notably, it serves as a tool for reporting the performance of programs and initiatives to the senior management and allows the organization to mobilize its resources and potential to reach high-priority objectives. Performance evaluation facilitates the improvement of products and services and the adjustment of programs and expenditures. The most important goals of performance evaluation include:

- *We identify the organization's strengths, weaknesses, and challenges and facilitate efforts to boost and enhance organizational capabilities and improve organizational activities.*
- *Improving resource allocation and making better use of human resources and capabilities in the implementation of envisioned programs*
- *Enhancing the organization's ability to provide services at higher qualities and quantities and maintain competitiveness in both national and international markets*
- *Increasing the efficiency and effectiveness of the organization*

From the above, it can be concluded that measuring and evaluating organizational performance and managing strategic alignment are among the core skills that managers need to master. When done effectively, consistently, and systematically, performance evaluation can enhance resource management and customer satisfaction, contribute to national development, create new capabilities, promote sustainability, and improve the global standing of the company or institution (Marco and Bititci, 2006). The process to be used for this control and evaluation must match the goals and strategies of the organization, must be comprehensive and cover all angles, and finally, must be able to encompass all the components of the organization together. Among the methods proposed for organizational performance evaluation and guidance, a balanced scorecard enjoys an exceptionally high degree of popularity and credibility among academics and researchers, who have used it extensively for strategic planning and organizational performance management over the past decades. Among the various methods that have been proposed so far to evaluate and guide the performance of organizations, the interest of members of academies and researchers has increased in the last decade about the influence and validity of the balanced scorecard on the performance of the organization and strategic planning (Nikkhah *et al.*, 2017). Strategic performance management methods are the Balanced Scorecard (BSC) and Strategy Maps (SMs) designed by Kaplan and Norton (Kaplan and Norton, 1992, 1996; 2004). This technique, provided by Kaplan and Norton, was designed as a strategic performance management tool to help transform organizational strategies into practical plans (Cebeci, 2009). BSC examines the company's activities from four perspectives: financial, customer, learning and growth, and internal business processes. In this version of BSC, the outputs from each perspective serve as performance measures for the following perspective. This early version of BSC has been widely used in many services and manufacturing companies, nonprofit organizations, government agencies, and industries worldwide. The purpose of the BSC is to implement the company's strategy through more operational terms (Ebrahimi and daneshvar, 2021). By integrating the business's financial, customer, and internal processes, and growth and learning

perspectives, BSC gives managers an insight into the myriad of relations between these aspects and their logical implications. This insight helps managers think beyond traditional notions of job obstacles and ultimately improve decision-making and problem-solving in the organization. BSC and the strategy map obtained from this method also facilitate the adjustment and execution of strategies by helping the management teams review planning processes and strategic plans. The municipal organization in Iran, given its significant role in the country, requires a precise assessment of the performance of each of its existing sectors so that by increasing the efficiency and productivity of these sectors, a pathway for growth and flourishing in this area can be established. The purpose of this study is to provide a comprehensive framework for strategic decision-making in municipalities by integrating the Dynamic Balanced Scorecard with game theory. The framework is tested through simulations and real-world case studies. Based on such research, municipalities can use the Dynamic Balanced Scorecard and game theory to improve crisis management and resilience. The article provides practical recommendations for managing emergencies and ensuring continuity of public services. The study focuses on aligning municipal goals with stakeholder interests, optimizing resource allocation, and improving decision-making processes, providing insights into adaptive strategies for long-term performance improvement.

Literature review

Although BSC and SMs are among the most widely used methods for strategic performance management, despite these benefits, BSC has several weaknesses and limitations, as reported in the literature. Researchers have tried to overcome this by combining it with other management tools such as the Analytical Hierarchy Process (AHP), the Analytical Network Process (ANP), and knowledge-based systems. For example, Modak *et al.*, (2017), Lin, Fu-Chiang, Yi-Hui (2023), Chen, *et al.*, (2023), Ghafournia, Ghavidel, Behboudi (2022), and Keshavarznia and Wallace (2023) used the AHP methodology as a supplement to BSC, Leung *et al,*. (2006), Tseng *et al.*, (2007) and Dincer *et al.*, (2016), Lin, Wen Cheng (2022), Quezada *et al.*, (2022), Rösner and Bredebach (2022) combined the BSC with ANP, and Kunz and Schaaf (2011) and Bobillo *et al.*, (2009) used the knowledge-based systems to improve BSC. Given the importance of BSC and its popularity among researchers, the literature contains many articles combining BSC with different management tools. Systems dynamics is another efficient management methodology that can complement BSC to overcome its limitations. The works carried out by Nielsen and Nielsen (2010), Barnabe (2011), othman (2008), Buytendijk *et a.,l* (2010), and Khanmohammadi *et al.*, (2022) are examples of the integration of BSC with system dynamics. Yildiz *et al.*, (2020) provide a research study on the development of a dynamic strategic plan using a dynamics modeling system to enhance the strategic performance management process in collaboration with one of the largest international construction companies in Turkey, which is listed among the top 100 international construction firms in Engineering News-Record ENR (2018). Akkermans and Van Oorschot (2005), in your paper, System Dynamics (SD) is used as an approach to overcome the limitations of BSC theory. This paper develops a two-stage process of system dynamics modeling and BSC. This process includes a qualitative and quantitative stage in system dynamics modeling. Managers found the BSC helpful in achieving a list of financial and non-financial performance measures. However, they were unsure whether these measures were the right ones. Instead of assuming that their scoring is correct, the management team used a system dynamics-based approach to examine the relevance of existing metrics. Nielsen and Nielsen (2013) show the possibility of linking an existing BSC framework to a System Dynamics Modeling (SDM) approach and how such a model can be used for simulation to help the participant understand different possible strategies. The article's approach shows how different criteria and indicators can provide a basis for the further development of BSC into a quantitative strategic model. A case study has clearly shown that if the firm has the opportunity to evaluate the financial benefits of various simple initiatives, an SDM approach is needed. Oladimeji *et al.*, (2020) scoping study showed that many articles use the BSC as a PM guidance framework. There are several levels in the organization where SD is applied (e.g., business units, department / functional levels, and organizational levels). Oladimeji *et al.*, (2021). It has been argued that since the advent of the Balanced Scorecard in the early 1990s, research has

extensively discussed the problems of cause-and-effect relationships, time delay, elements between criteria, and the perspectives and concepts of feedback loops. Their paper focuses on using a system dynamics modeling approach to address these three problems. Ebrahimi and Daneshvar (2021) developed a dynamic model based on the financial perspective of a balanced scorecard in a case study of a service-oriented company in a telecommunications company. Therefore, it provides knowledge and information for academics and BSC and SD practitioners to implement BSC-based SD in companies, especially service-based companies. A dynamic system is a solution to overcome the bottlenecks of the strategic plan and the traditional balanced scorecard, which are static, and manage strategic performance (Yildiz *et al*., 2020). Interpretive causal loop diagrams, stock, and flow diagrams, and simulation results enable us to understand system behavior. Insight into the application of system dynamics in performance management is a forward-looking perspective that overcomes the limitations of a static performance management system (Yadav, 2020). The relationship between BSC variables is a one-way cause-and-effect relationship. So it can tend to be indifferent to its implementation; in fact, there are various interactions, especially delays between decision-making and critical performance indicators. BSC is not a separate cause-and-effect relationship in the context of time (Theresia *et al.*, 2016). Existing planning tools, such as BSC, have limitations, such as dependence on the developer, weakness in showing time delays, as well as mathematical relationships between lead and lag indicators (Khakbaz and Hajiheydari, 2015). The literature, however, does not include a comprehensive examination of the advantages of using system dynamics in the implementation of BSC. The present study attempts to provide a better insight into how the system dynamics methodology can eliminate BSC limitations. Also, when many strategies are eligible for inclusion in analyses, research, and management teams may find it challenging to choose the best combination of strategies from among possible options. Therefore, there is a need for a suitable measure to facilitate this choice. Abedian, *et al.*, (2022). *Shapley value* is a measure that reflects how players interact with other players in the framework of coalitions in cooperative games Yousefi, *et al.*, (2022), mirmezhad, Seyyedi, Yousefi (2020). Kočišová *et al.*, (2024) in their paper, integrated the BSC-DEA model in an Industry 4.0 company to enhance performance measurement by utilizing advanced technologies for real-time KPI monitoring. This approach optimizes operational efficiency and supports continuous improvement in a digital environment, fostering agile, data-driven decision-making for a sustainable competitive advantage. Oliveira *et al.*, (2024). This research shows that the characteristics and benefits of the BSC are confirmed by the managers of the main exporting organizations in Portugal, regardless of whether they have the BSC implemented or not. In companies that do not have the BSC in place, managers agree that if the BSC were implemented, it would support strategic focus and improve the monitoring of organizational performance. Keraa *et al.*, (2024), Measuring the performance of dental schools in research using a balanced scorecard. This research showed BSC is an efficient tool for the measurement of the performance of the departments at medical colleges. Mayo-Alvarez *et al.*, (2024), used a dynamically balanced scorecard design as an industrial safety management system in Peru's metallurgical mining sector. In this study, Shapley's value determines the best combination of strategies.

MATERIAL AND METHODS

Balanced scorecard

Initially developed by Kaplan and Norton (1996), the BSC introduces four management processes that, together and separately, facilitate linking long-term strategic goals with short-term activities. Kaplan and Norton (2004) also created a powerful strategy map tool. Companies can use it to describe the links between intangible assets and value creation with high precision and clarity.BSC model assumes that four groups of activities are likely to be critical for most organizations at all levels of sophistication: investing in growth and learning capacities, improving the efficiency of internal processes, creating customer value, and increasing financial success. (Kaplan and Norton, 2004). The essential advantages of BSC are as follows. Use of a few measures: BSC hypothesizes that a handful of well-thought-out criteria can gauge an organization's performance. In contrast, older performance measurement practices use a host of indicators and criteria, which causes a heavy information load and confusion among managers. In

general, BSC prescribes using at most 5 criteria for each aspect, which makes sense given the limitations of organizational performance management (Akkermans and Oorschot, 2005; Abdurrachman *et al.*, 2022). Bridging different domains: BSC keeps the managers focused on a balanced set of performance criteria encompassing both financial and non-financial aspects of the organizational activity (Kaplan and Norton, 1996). Forcing the management team to reexamine their beliefs and assumptions: BSC forces managers of different units to reexamine their beliefs during meetings and deliberations, and thus helps them reach a degree of convergence in ideas, which will positively impact the organization's performance. In other words, BSC allows managers to share and discuss their subjective models of organizational processes in meetings, which is expected to result in the correction or completion of these models (Bobillo *et al.*, 2009; Faraji *et al.*, 2022).

Limitations of BSC

The essential limitations of BSC are as follows

Unilateral cause-and-effect relationships: The constituting elements of an organization both affect and are affected by each other, reflecting the presence of feedback between cause-and-effect relationships. However, in the strategy maps of BSC, these relationships are unilateral and flow toward the financial perspective, which is not entirely realistic (Bianchi and Giovan Battista, 2008).

Lack of consideration of time delay: In the BSC strategy maps, it is assumed that causes have an immediate impact on effects. However, since some cause-and-effect relationships have an inherent delay, this assumption may lead to inaccurate conclusions (Nielsen and Nielsen, 2008).

Lack of an accurate validation process: BSC involves considering a small number of criteria as key performance measures. Although using a few criteria is one of the advantages of BSC, it is sometimes difficult to decide whether the criteria are chosen correctly and whether they are indeed the most important, as BSC does not provide any mechanism for validating the defined criteria. The validity of BSC hypotheses about cause-and-effect relationships between performance criteria has been questioned in the literature (Bianchi and Giovan Battista, 2008).

Poor link between strategy and operations: One of the critical challenges in using BSC is making operational forces engage with organizational strategies, as BSC does not provide any means in this regard (Seyyedi *et al.*, 2016).

Excess focus on intra-organizational affairs: BSC fails to see the organization as a value chain whose success depends on the positive participation of employees, suppliers, and shareholders. It also fails to answer a key question for managers: What are the competitors doing? (Othman, 2006).

Static nature: Because of the static nature of BSC, managers who rely too much on this tool cannot adopt suitable strategies when encountering changes. BSC prescribes decision-making based on a snapshot of the organization's condition. However, in reality, the business environment is very dynamic, and the organization has to adjust its strategies to the change in circumstances (Qi *et al.*, 2009).

Linear relationships: BSC assumes linear relationships between the effects of strategies and, consequently, performance criteria, which is not a realistic assumption. These relationships are usually nonlinear and behave differently over short-term and long-term periods (Qudrat-Ullah, 2009).

Lack of a measure for strategy selection: In BSC, when there are many possible strategies for achieving the desired objective, choosing the best combination of strategies could be a challenge. BSC does not provide a solution to address this. For example, with only 3 strategies in each perspective, there will be 81 ($=3^4$) different combinations of strategies, which makes it very difficult to anticipate the outcomes and determine which combination best serves the objectives (Leung, 2006).

System dynamics

Jay Forrester was the first to introduce the concepts known today as System Dynamics (SD). These concepts were first expanded based on the tools control engineers use to analyze control systems' mechanical and electrical stability (forrester, 1961). Building a system dynamics model consists of 3 basic parts, which are:

- *Dynamic hypothesis.*
- *Causal loop diagram.*
- *Stock and Flow diagrams.*

The dynamic hypothesis is a model of how the studied system works, its boundaries, and the relations between its components. A causal loop diagram is used to illustrate and better understand

dynamic relationships, interactions, and feedback loops between system elements. In this diagram, each relationship is represented by an arrow with a sign showing the causal relationship's direction. The positive sign on the arrow indicates that, if other factors are fixed, a change (increase/decrease) in the factor at the origin of the arrow will cause a likewise change (increase/decrease) in the factor at the end of the arrow. The negative sign indicates that the change in the first factor will change the second factor in the opposite direction. The primary purpose of Stock and flow diagrams is to illustrate the relationships between flow and stock variables in an SD model. Here, stock variables represent the accumulation of resources or values that reflect the system's state, and flow variables represent the changes over a unit of time that increase or decrease the stock variables. Auxiliary variables and constants are also used in this diagram (Najibi *et al.*, 2022).

Use of SD to overcome the limitations of BSC

System dynamics can be used to overcome the limitations of SM and balanced scorecards. (Yildiz *et al.*, 2020) In this section, various applications of system dynamics in improving the balanced scorecard are comprehensively discussed.

Using feedback loops to avoid unilateral causal relationships

Feedback loops can serve as very effective tools for understanding the relationship between elements of a strategic plan. In the real world, causal relationships are rarely unilateral. Many researchers have avoided this problem by using the features of SD in the BSC process to create dynamic strategy maps.

Creating the possibility of lag in causal relationships

One of the features of SD, which is also available in the related software, is the ability to define lags for equations. For example, one may define a lag between the start of training and the actual improvement in the employees' knowledge, which could take as long as the duration of training.

Accurate validation

Unlike BSC, SD has a specific mechanism for model validation, which is extensively discussed in the literature. Also, SD has been widely used to quantify qualitative models and validate qualitative assumptions about strategies and policies. In general, humans are not good at understanding the dynamic behavior of qualitative constructs. Even if the effect of every single policy on a performance criterion is perfectly understandable, it would be nearly impossible to analyze the results of multiple simultaneously implemented policies without computer simulation.

Linking strategy and operations

Creating SD models begins with identifying critical operational elements and processes in the organization, which requires a close relationship with operational levels. Furthermore, SD is a tool designed for strategizing purposes and therefore creates a strong link between strategies and operations.

Expanding the scope of the BSC process

Using SD, one can expand the boundaries of the analysis to include critical environmental factors that affect the organization, such as competitors and suppliers. For example, Qi *et al.*, (2009) used a BSC-based approach to create SD models for two main competitors in the Chinese mobile market and suggested strategies for each organization.

Introduction of dynamism to BSC

By considering the dynamic nature of strategies and their changes over time, SD gives managers a good insight into how the system behaves in the face of changes and helps them adopt a suitable strategy accordingly. In the event of a significant change in environmental conditions, it also helps the managers recalibrate the model with new input data so that the outputs account for the new situation.

Use of nonlinear relationships

SD simulation software allows nonlinear relationships, tabular data, and logical relationships to make the model more realistic.

Prediction of strategy outcomes by simulation

As explained, one of the BSC team and management challenges is how to select the best combination of strategies. Many researchers have proposed using multiple-criteria decision-making methods for this purpose. However, the human mind cannot quickly analyze complex third-order and higher-order systems, and the problem becomes

even more complex when two or more strategies are implemented together. Hence, multiple-criteria decision-making methods based on the subjective analysis of managers cannot be sufficiently reliable. SD lacks the limitations of the human mind and can, therefore, be used to predict the outcomes of multiple strategies, whether they are implemented separately or together. However, this does not eliminate the challenge of choosing the best combination of strategies. In this study, this issue is resolved using Shapley's value in game theory and, more specifically, cooperative games.

Shapley value

In a cooperative game, the Shapley value is the average benefit that each player gains because of participation in the coalition. In other words, this concept represents the payoff received by player i in the coalition because of its contribution to the coalition, which is denoted by u_i^*. The contribution of the player i to the coalition C is defined as Eq. 1:

$$\{V(G)-V(G-(i))\} \quad (1)$$

Assuming that the coalition grows from one member to two, three, and ultimately N members, and members can join in any order, then the average marginal contribution of player i to the coalition, u^*_i, will be:

$$u_i^* = \sum_{\substack{C\subset N \\ i\in C}} \frac{(k-1)!(N-k)!}{N!}\{V(G)-V(G-(i))\} \quad (2)$$

where

N: the total number of players

k: the number of players in the coalition G

$\frac{(k-1)!(N-k)!}{N!}$: the probability of a coalition

Eq. 2 is obtained by summing the formulation for each possible coalition with player i.

Shapley value (u_i^*) signifies the power of the player i and how crucial it is for the success of the coalition. This power depends on how much a player increases the power of a coalition once it joins that coalition. In this study, each perspective is given a utility value in the range of 0 and 5 depending on the simulation outcomes for each strategy combination. Thus, for each strategy combination, there are four utility values u_F, u_C, u_I, and u_L, which pertain to financial, customer, internal processes, and learning and growth perspectives, respectively. Then, the utility of two-, three -, and four-member coalitions for each strategy combination is calculated as shown in the following example. What is calculated in this example (Eq. 3) is the utility of the coalition of financial and customer perspectives for the strategy combination $F_1C_1I_2L_2$.

$$U_{F,C}(F_1,C_1,I_2,L_2)=U_F(F_1,C_1,I_2,L_2)+U_C(F_1,C_1,I_2,L_2) \quad (3)$$

According to the Von-Neumann and Morgenstern theorem, for a normal form (two-dimensional) game, the characteristic function value (V(G)) for a coalition has the characteristics of a saddle point. The maximin of the rows and the minimax of the columns intersect at a saddle point because, in the rows, coalition members are trying to maximize their minimum utility, and in the columns, non-members are trying to minimize their maximum loss. Although non-members may have a positive gain anyway, a lower payoff for coalition members may grant non-members a higher payoff. For a normal-form (two-dimensional) game, the characteristics of the saddle point caϕn be obtained by solving an L-P (for the coalition members of the same row). The V(G) defined for a two-dimensional and non-zero game (consisting of N players) satisfies V() =0 and the "super additivity" property. Hence, if G_{ij} is the utility of the coalition at the ith row and the jth column of the coalition matrix (coalition G), where the ith row represents the combinations of coalition strategies and the jth column represents the combinations of non-coalition strategies, then V(G) is obtained by solving the following LP:

$$\begin{aligned} &V(G)=MAX:z \\ &s.t. \\ &z\le\sum_i p_i * G_{ij} \rightarrow \forall j \\ &p_i \ge 0 \\ &Z: free \end{aligned} \quad (4)$$

Here, p_i denotes the probability of selection from the strategy combinations of the i-th row. To obtain the characteristic function of different coalitions of BSC perspectives, we rewrite the linear program of Eq. 1 based on the normal form utility

matrix of coalition C and then compute the V(C) of each coalition by solving the model with the software Lingo. Finally, we compute the Shapley value of each player (perspective) and determine the best strategy combination accordingly. This section presents the conceptual framework of the proposed system of performance evaluation based on the balanced scorecard, system dynamics, and game theory (Fig. 1). This conceptual framework consists of two major parts, dynamic BSC and game theory, with the first part composed of two sub-parts, BSC and system dynamics. The introduced framework consists of seven steps. Two steps are dedicated to BSC, one step is shared between BSC and system dynamics, another two steps are dedicated to system dynamics, and the last two steps are related to game theory.

Method steps

The first step involves a careful and thorough examination of the organization to understand its nature, size, processes, products, and other core elements. The importance of this step stems from the fact that it is impossible to evaluate an organization properly without having a good understanding of its processes and objectives. The second step is to identify the key indicators of organizational performance through interviews with managers and experts of the organization. The third step is to create

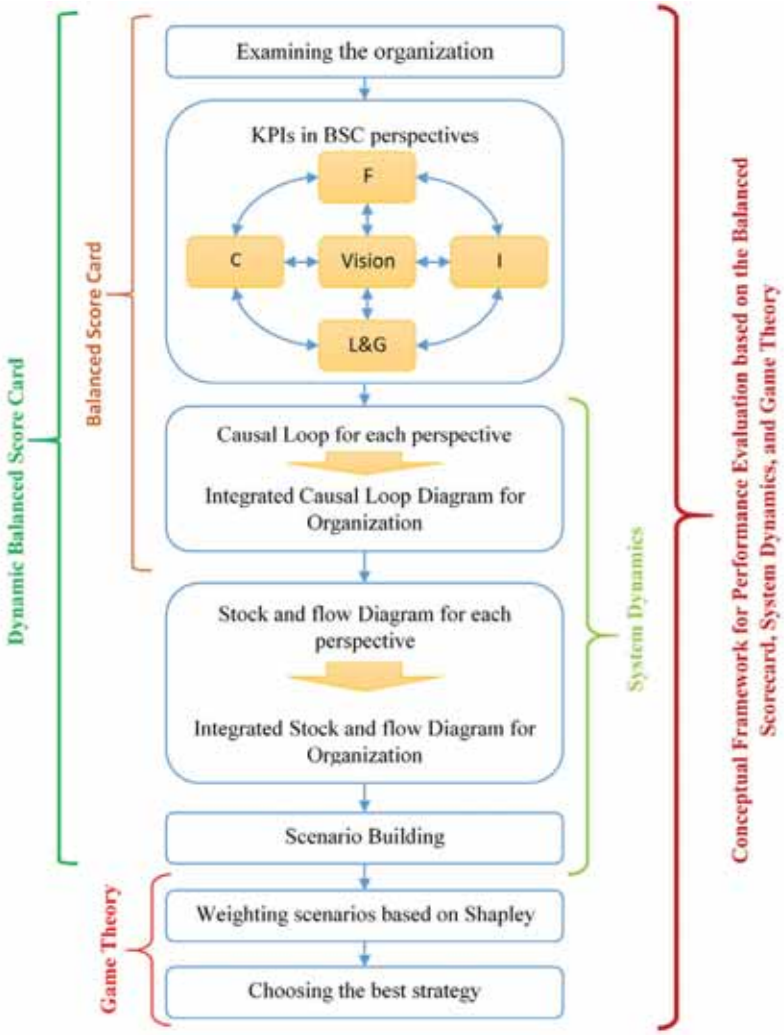


Fig. 1: The proposed conceptual framework for strategic performance management based on the balanced scorecard, system dynamics, and game theory

the dynamic SM of the organization based on system dynamics-modified BSC perspectives and causal loop diagrams. In this step, the performance criteria obtained in the previous step are used as the main elements of the causal loop diagram, and their cause-and-effect relationships and feedback loops formed in these diagrams are identified separately for each BSC perspective. In the fourth step, the causal loop diagrams formed in the previous step are used to compute the stock and flow variables for each perspective and draw the stock and flow diagrams accordingly. Next, the inter-variable relationships and equations are derived based on the organization's statistical records and experts' opinions. Finally, the developed models are integrated to reach a comprehensive stock and flow model for the organization. The fifth step is to create different scenarios for improving organizational performance from each BSC perspective based on simulation results, as well as objectives and the current condition of the organization. In this study, we have considered 3 strategies for each perspective. In the sixth step, the game theory model is run for different combinations of strategies, with each BSC perspective considered a player. After obtaining the utility of each strategy combination, the Shapley value of each player is computed. Finally, in the seventh step, the Shapley values obtained in the previous step are used to identify the best strategy combination for the organization.

RESULTS AND DISCUSSION

The municipality of District 4 in Tehran is responsible for managing one of the City's largest and most populous urban districts. The population of this district is about 10% of the total population, while the city has 22 urban districts. This district has exciting features and potential, including undeveloped lands, a strategic role in urban water and electricity provision, extensive small business activity, and giant forest parks, which cannot be managed appropriately and utilized without an efficient municipality organization. In this case study, the proposed method of performance evaluation, which we call dynamic BSC, is used to evaluate the performance of the District 4 Municipality.

Identification of critical performance criteria

To identify the critical performance criteria of the organization, we developed a four-part questionnaire encompassing the four perspectives of the balanced scorecard. Each part of this questionnaire contained several standard criteria for evaluating service and government organizations from one perspective. The questionnaire was filled out by the middle and senior management of the municipal organization, including 17 people. The results obtained from this questionnaire are presented in Table 1.

Causal loop diagram

Using the identified performance criteria as the basis of work, we examined the cause-and-effect relationships and feedback loops between the elements of the organization in each perspective to reach a causal model for the organization. The resulting causal loop diagram consists of 4 segments, each dedicated to one BSC perspective. These segments are linked by logical relations between the elements, creating an integrated causal loop diagram. The most important outcome of this step is giving managers a better understanding of organizational procedures and a uniform subjective perception of organizational processes. As shown in Fig. 2, the elements of different perspectives from multiple feedback loops signify the dynamism of their behavior. For example, employee satisfaction, service time, work in progress, and work pressures form a positive loop. Increased employee satisfaction reduces service time (negative relationship), increased service time increases work in progress (positive relationship), increased work in progress increases work pressure (positive relationship), and increased work pressure decreases employee satisfaction (negative relationship). Because of the many negative relationships between these components, they form a positive loop.

Stock and flow model

This step of the work involved developing the stock and flow model in the software Vensim PLE based on the obtained causal loop diagram and gathered organizational data (Fig. 3). Simulations were performed for 10 years at 1-year steps.

The stock and auxiliary variables used in the stock and flow model are briefly explained below.

Stock variables

Automation: This stock variable represents the percentage of IT-based administrative and service processes from the total.

Table 1: Performance criteria identified for the District 4 Municipality

Cronbach's alpha	Value	KPI	Perspective
0.78	4.3	Total Cost	Finance
	3.2	Growth of financial resources	
0.69	2.7	Advertising	Customer
	3.2	Service quality	
	3.2	Service time	
0.72	4	Citizens satisfaction	Internal Process[
	4.1	employee satisfaction	
	3.8	Throughput	
	3.5	Automation	
	2.9	Work pressure	
0.68	3.3	Research and Development	Learning & Growth
	3.7	Investing in information technology	
	2.9	Staff training	

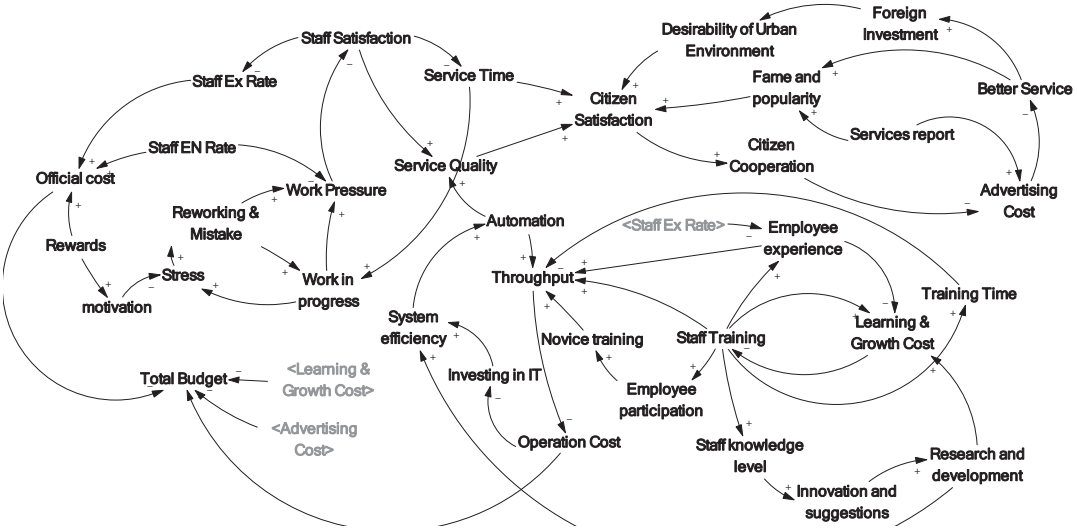


Fig. 2: Causal loop diagram developed for the District 4 Municipality (Tehran, Iran)

Training time: This variable is the total duration of training that each employee receives in hours.

Staff satisfaction: This variable represents the degree of employee satisfaction with the organization in percentage.

Work pressure: This variable represents the number of work tasks employees have to complete relative to their power and available time.

Throughput: This represents the staff's power in managing and executing the assigned duties in percentage.

Foreign investment: This is the private investment absorbed in different sectors, such as workshops, commercial and retail businesses, urban services, etc.

Citizen satisfaction: This variable represents citizens' satisfaction with the activities and services of the organization.

Profit: This is the difference between the costs incurred in different sectors and the earned revenues or cost savings made in the future.

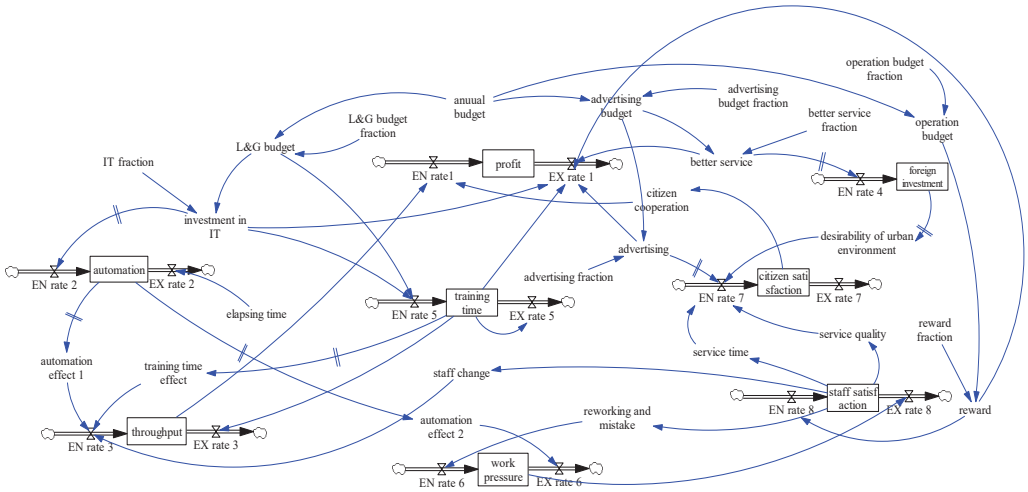
Auxiliary variables

Annual Budget: The annual budget is considered fixed and does not include the effect of inflation.

L&G Budget: This is the budget devoted to learning and growth activities

L&G Budget Fraction: This is the fraction of the total budget allocated to the L&G activities.

Investment in Information Technology (IT): This represents the amount of investment made in the



blue

Fig. 3: Stock and flow diagram developed for the District 4 Municipality (Tehran, Iran)

IT infrastructure and integrated processes of the organization

IT Investment fraction: This is the fraction of the L&G budget that is allocated to investment in IT

Elapsing time: Given the importance of access to up-to-date technologies, this variable is intended to represent the effect of the passage of time on information technology.

Automation effect 1: This variable represents the effect of automation on throughput

Automation effect 2: This variable represents the effect of automation on work pressure

Training Time effect: This is the impact of training time on throughput

Staff turnover: This variable represents the extent of employee turnover, which depends on their satisfaction and affects their throughput.

Service quality: This represents the quality of services provided by the staff, which depends on their satisfaction.

Service time: This is the time it takes for the staff to provide services, which depends on their satisfaction.

Operation budget: This is the budget allocated to the operations division and includes all organizational activities of the municipality in different parts of the district.

Operation budget fraction: This is the fraction of the total budget allocated to the operations.

Reward: This variable represents the rewards and benefits paid to the employees.

Reward fraction: This is the fraction of the operating budget allocated to rewards.

Duplicate work and mistakes: This represents the duplication rate of work and mistakes.

Advertising budget: This represents the budget allocated to the activities related to the customer perspective.

Advertising budget fraction: This is a fraction of the total budget for advertising.

Better service: This represents the costs incurred to attract private investment and ensure customer satisfaction.

Better service fraction: This is the fraction of the customer perspective budget allocated to service improvement.

Citizen cooperation: This represents citizens' cooperation in observance of laws, urban hygiene, protection of urban assets, and others.

Advertising: This represents reporting finished and ongoing services and advertising to attract private investment.

Advertising fraction: This is the fraction of the customer perspective budget allocated to advertising.

The desirability of urban environment: This represents the desirability of urban areas in terms of employment and living conditions.

Simulation results

The simulation results obtained for the criteria employee satisfaction, citizen satisfaction, work

pressure, throughput, and automation are presented in Fig. 4 (all values are in percentages). Figs. 5 and 6 display the results obtained for for-profit and foreign investment (in 10^7 Rials) and the training time (in hours/person), respectively.

The obtained simulation results provide several

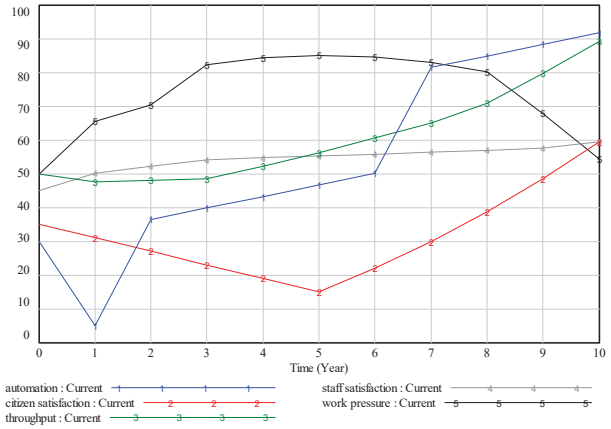


Fig. 4: Simulation results for the criteria automation, citizen satisfaction, throughput, employee satisfaction, and work pressure (in percentage)

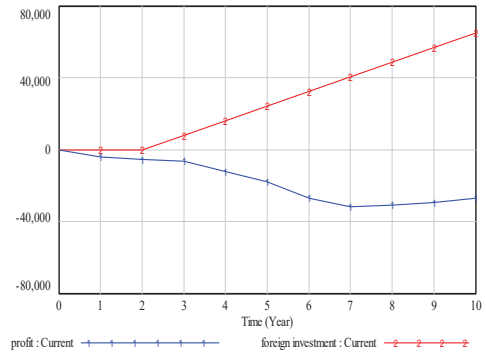


Fig. 5: Simulation results for the criteria foreign capital and profit (in 107 rials)

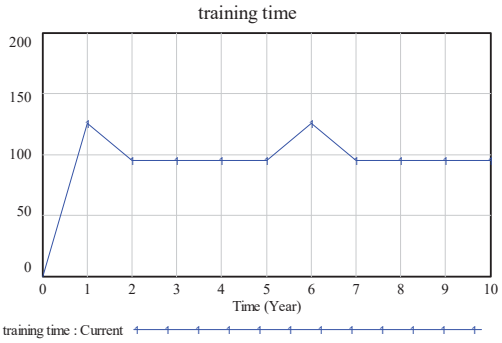


Fig. 6: simulation results for the criterion training time (in hours/person)

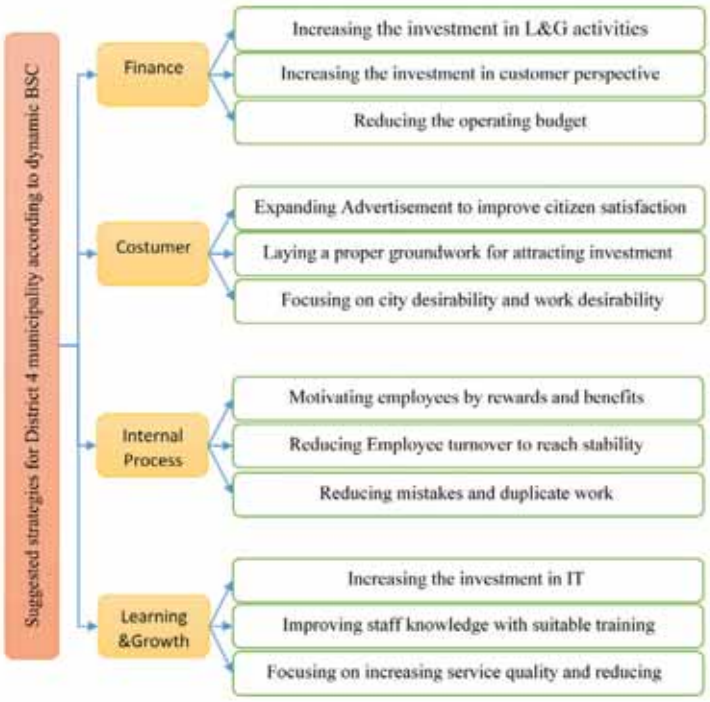


Fig. 7: Suggested strategies for each perspective

Table 2: Utility values of players for each strategy combination

F_i	C_i	I_i	L_i	U_F	U_C	U_I	U_L
1	1	1	1	3	5	1	4
1	1	1	2	2	1	3	5
1	1	1	3	0	4	3	4
1	1	2	1	4	3	0	1
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
3	3	3	2	4	5	3	1
3	3	3	3	1	5	3	1

important insights that should be well-considered in plans. These insights are summarized below:

1. A sharp decline in citizens' satisfaction in the first 5 years of the simulation,

2. A sharp decline in automation in the first 2 years of simulation,

3- Realization of employee satisfaction by about 60%,

4- Relatively long payback time (about 7 years).

Scenarios

In this part of the work, simulation results, which reflect the organization's condition in the next 10 years in terms of BSC criteria, were used to choose three strategies for each perspective. These strategies are given in Fig. 7.

Game theory-based weighting

As shown in Table 3, different combinations of BSC strategies were simulated in this step. As shown in Table 2, the simulation results assigned a utility value between 0 and 5 to each perspective (player).

Next, the approach described was used to compute the characteristic function of the coalitions and the Shapley values of each player. In this step, we formed 15 standard form utility matrices for the coalitions and

Table 3: Structure of cooperative games in BSC (3 strategies per player)

Structure of cooperative games in BSC										
		Learning and growth								
		I			II			III		
Internal processes	I	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)
		Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)
		Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)
	II	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)
		Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)
		Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)
	III	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)	Customer (I) Financial (I)	Customer (I) Financial (II)	Customer (I) Financial (III)
		Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)	Customer (II) Financial (I)	Customer (II) Financial (II)	Customer (II) Financial (III)
		Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)	Customer (III) Financial (I)	Customer (III) Financial (II)	Customer (III) Financial (III)

solved one linear programming model for each matrix to determine the characteristic function value for each coalition, shown in Table 4. Using the obtained characteristic function values, the Shapley value of each player was calculated, shown in Table 5.

Strategy selection

Given the Shapley value obtained for the players, the relations of perspectives in criticality for coalitions were C> L> I> F. Hence, the customer perspective seems to play a decisive role in the choice of strategy combinations for the studied case. For this case, the following most essential perspectives for strategy selection were learning and growth, internal processes, and financial, in that order. Among the 81 different strategy combinations with different payoffs for the players, in 12 combinations, the customer perspective has a payoff of 5. Therefore, the strategy of the customer perspective will be chosen from among these 12 combinations. Fig. 8 illustrates choosing the best strategy combination among 12 combinations with a payoff of 5 from the customer's perspective. After the customer perspective, the L&G perspective tries to maximize its payoff and chooses the combination accordingly. This process continues until the last player selects a strategy combination. If the player "customer perspective" chooses strategy 1 (from among all strategy combinations with a payoff of 5), then the player "L&G perspective" has to choose between strategy 1 with a payoff of 4 and

Table 4: Characteristics function values obtained for each coalition

	V
V(F)	1.25
V(C)	1.818182
V(I)	1
V(L)	0.9
V(F,C)	5.310345
V(F,I)	5.57143
V(F,L)	5.44118
V(I,L)	5.251917
V(C,L)	5.516854
V(C,I)	5.5
V(F,C,I)	10.8636
V(F,C,L)	11.18182
V(F,I,L)	9.62857
V(C,I,L)	12
V(F,C,I,L)	19

Table 5: Shapely values of the players

	Shapley value
F	3.78
C	5.38
I	4.59
L	4.64

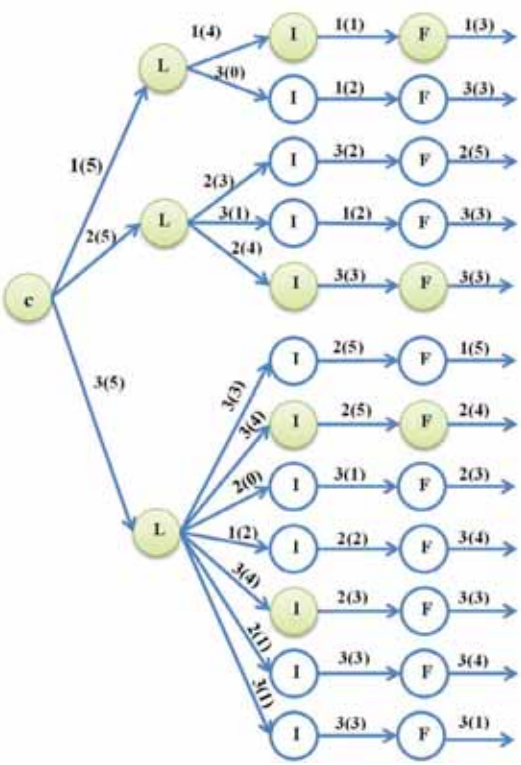


Fig. 8: Process of choosing the best strategy combination

strategy 3 with a payoff of 0, in which case it will select strategy 1. With this selection, there will be no choice for other players (internal processes and financial), and they will be forced to choose strategies 1 and 1 with payoffs of 1 and 3. Therefore, the strategy combination $C_1L_1I_1F_1$ can be considered the best choice for the studied case. Suppose the player's "customer perspective" chooses strategy 2. In that case, the player "L&G perspective" will choose $C_2L_2I_3F_3$ with a payoff of 4 (the highest receivable), and again, there will be no choice for other players, and they will have to accept the same combination. If the player "customer perspective" chooses strategy 3, then the "L&G perspective" can choose either $C_3L_3I_2F_2$ or $C_3L_3I_2F_3$, yielding the same maximum payoff. Hence, the player's "internal processes perspective" has to choose between these two combinations, and its choice will be $C_3L_3I_2F_2$ because it gives a higher payoff.

DISCUSSION

The simulation results give an overall view of the strategic performance management for the Tehran Region 4 Municipality. The observations show a decline in citizen satisfaction and automation during the initial two years of implementation. This might indicate that while new strategies are being implemented, the transition period poses a challenge in terms of the quality and efficiency of services in the short term. However, as the system gets stabilized, results reflect an upward trend in key performance areas that show positive long-term benefits of the strategic adjustments. In the course of the simulation, satisfaction reached about 60%, which is indicative of balanced success in managing internal workforce grievances. The interlink between satisfaction and throughput growth indicates that better investment in people and internal improvements leads to improved municipal performance, which further establishes the need for structured training with incentives to help maintain motivation and productivity among staff. It also indicates that financial performance remains the least important as compared to customer satisfaction, learning, and growth. While financial strategies contribute to stability, their impact is less immediate compared to customer-oriented and internal growth initiatives. This finding supports the need for a balanced approach where financial considerations support broader organizational objectives rather than being the main focus.n Moreover, game theory, through the Shapley value, indicates the importance of considering the customer perspective in strategic decisions. The results show that customer-related strategies yield the highest payoff and, by extension, indicate that municipalities must adopt strategies that conform to the expectations of the citizens. Secondly, the high emphasis on learning and growth indicates that continuous development of skills and technological investments are important for long-term strategies. Lastly, the simulation results indicate that even though there could be initial setbacks, a concerted effort greatly improves the performance of municipalities in the long term. A payback period of about seven years implies that one needs to be patient to realize strategic benefits. The policymakers must be forward-looking and ensure sustained and continued efforts at implementing policies that drive the success of municipalities. The selection of the optimal combination of strategies pinpoints a step-by-step approach toward better municipal performance in terms of financial, customer, internal process, and learning and growth perspectives. Three of the best strategy sets, namely (C1, L1, I1, F1), (C2, L2, I3, F3), and (C3, L3, I2, F2), depict different ways of tackling major municipal challenges and further aligning the strategies. The first combination, C1-L1-I1-F1, integrates citizen engagement with IT development, employee motivation, and increased investment in learning and growth. Increased advertisement, C1 is likely to increase the satisfaction of citizens through the promotion of municipal initiatives and transparency. At the same time, the investment in IT, L1, enhances automation and, hence, the efficiency of operation. Similarly, the motivation of employees by rewarding them, I1, translates into a gain in productivity and service quality. Finally, increasing investment in learning and growth (F1) ensures that municipal staff continuously develop skills relevant to evolving urban management needs. The second combination, C2, L2, I3, F3, adopts a more cost-conscious approach while maintaining efficiency improvements. Laying the groundwork for attracting investment (C2) strengthens financial sustainability by increasing private sector participation in municipal projects. Improved staff training develops a knowledgeable and adaptive work group, better ready for changes related to technology or procedures. Additionally, the impact of reduced mistakes and rework optimizes operations internally and helps

reduce the loss of resources within the same resource pool. This is simultaneously enabled by a decrease in the operating budget, while the reallocation of the funds supports more vital municipal functions with no compromise on service quality. C3-L3-I2-F2 allows urban development priority, quality services, workforce stability, and customer involvement: Focusing on city and work desirability, C3 attracts skilled labor and investment, contributing to long-term economic growth. Enhancing service quality with less inefficiency, L3, guarantees citizens receive high-value services with little delay. Reduction in employee turnover, I2, stabilizes workforce competency and improves municipal performance. Finally, strategic investment in customer perspectives, F2, will ensure that the needs of the public remain at the center of decisions and thus achieve better satisfaction and trust by citizens.

Management recommendations based on the results of communication

• *Develop a transparent communication strategy:* Establish a structured approach to regularly update citizens and employees about ongoing municipal initiatives, addressing concerns and clarifying objectives.

• *Enhance stakeholder engagement:* Create forums, surveys, and interactive sessions where citizens can provide feedback and discuss municipal plans to ensure their needs are adequately considered.

• *Leverage digital platforms for information dissemination:* Use social media, municipal websites, and mobile apps to disseminate information on the progress of projects and policy changes in real-time.

• *Create a special task force for communication:* Establish a specialized team that shall be responsible for ensuring effective internal and external communication with regard to municipal strategies and developments.

• *Establish open channels for employee communication:* Clearly and transparently establish avenues of communication with employees from the management level to let voices be heard and strategic shifts be understood better.

• *Data visualization for clarity:* Key performance metrics and results are presented in charts, graphs, and other forms of infographic formats to be easily understandable, both for the employees and the public.

• *Regular public awareness campaigns:* Organize events and campaigns to create awareness among the citizens about municipal strategies, their benefits, and how they can contribute towards improvement.

• *Develop crisis communication protocols:* Prepare a standardized approach to handle unexpected disruptions in municipal services, ensuring timely and effective information dissemination.

• *Encourage two-way communication:* Offer multiple channels through which citizens and employees can be heard, including suggestion boxes, hotlines, and digital platforms for feedback.

• *Monitor and adapt communication strategies:* Continuously review the effectiveness of the communication efforts and adjust according to feedback and evolving municipal needs.

CONCLUSION

This study focused on this question: What are the limitations of the BSC as one of the most common methods, and how do we overcome these limitations? To answer these questions, first, the limitations of the BSC were reviewed. Then, the concepts of system dynamics and game theory were presented as effective tools to overcome these limitations. This paper presents a methodology for strategic performance management based on the balanced scorecard, system dynamics, and game theory. Simulation with system dynamics has created the ability to consider causal loops, time delay, and non-linear relationships in the balanced scorecard, which leads to dynamic analysis. Also, a simulation validation process is a definite process. Simulating operational strategies and analyzing their results creates a proper connection between strategy and operational outputs and improves decision-maker's perception of operational results. Finally, choosing the strategy combination using the Shapley value, based on the simulation results, instead of choosing it by the decision makers' intuition, makes the strategy selection process transparent and systematic. To analyze the effectiveness of the presented framework, a case study was carried out in the 4th district municipality of Tehran. First, through a questionnaire, 13 key performance criteria of this organization were identified in the 4 dimensions of the BSC. Then, these criteria became the basis for creating a dynamic balanced scorecard. By identifying

operational strategies in each dimension, these strategies were placed as simulation scenarios. The simulation results were scored by experts. The results show that the ranking of players based on Shapley's value is in the order of customer, growth, learning, internal processes, and finances. This process is a guide for decision-makers to choose an effective and synergistic strategy combination and avoid choosing conflicting operational strategies. For example, in the presented case study, if the customer is the most important player, chooses the first strategy, then the first strategy should also be chosen in growth and learning, internal processes, and financial processes, respectively. One of the aspects observed in the balanced scorecard and the conducted studies is the interplay between employee satisfaction and administrative processes in the context of internal processes. In some articles, a new perspective has been considered as employee satisfaction. Therefore, the development of the internal process perspective can be regarded as two aspects: employee satisfaction and administrative processes for future research. The case study conducted can be a guide for municipal organizations, in particular, and other organizations in general that decide to implement a performance evaluation system in their organization.

AUTHOR CONTRIBUTIONS

S.H. Seyedi analyzed, interpreted, and modeled. A. Yousefi Hanoomarvar performed the literature review, reviewed, and edited the wording, formatting, citing, and referencing.

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CONFLICT OF INTEREST

The authors declare that no potential conflicts of interest exist in publishing this work. Furthermore, the authors have witnessed ethical issues such as plagiarism, informed consent, misconduct, data fabrication, double publication or submission, and redundancy.

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ABBREVIATIONS (NOMENCLATURE)

F	Financial perspectives
C	Customer perspectives
I	internal processes perspectives
L	learning and growth perspectives
G	Coalition of players
u_i^*	Shapley value
N	The total number of players
K	The number of players in the coalition G
G_{ij}	utility of the coalition at the ith row and the jth column of the coalition matrix (coalition G)
$U_{i,j}$	utility of coalitions i and j
$V(G)$	characteristic function value for coalition G
p_i	probability of selection from the strategy combinations of the i-th row
BSC	Balanced Scorecard

AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
ENR	Engineering News-Record
SD	System Dynamics
SDM	System Dynamics Modeling

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ORIGINAL RESEARCH PAPER

Assessing environmental concerns, technological usefulness, and adoption drivers of electric three-wheelers in urban transportation systems

T.D. Pushpam[1,2], T. Chandrasekar[1], D. Sivakumar[3,*]

[1] *Department of Business Administration, Kalasalingam Academy of Research and Education, Krishnankoil, Srivilliputhur, Tamil Nadu 626126, India.*

[2] *Department of Business Administration, Saintgits Institute of Management, Kottayam, Kerala, India.*

[3] *Kalasalingam School of Agriculture and Horticulture, Kalasalingam Academy of Research and Education, Krishnankoil, Srivilliputhur, Tamil Nadu 626126, India.*

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study aimed to examine the factors influencing Switching Intentions toward electric three-wheelers within the urban transportation context of Kerala, India. Given the increasing need for sustainable urban mobility, understanding the behavioural drivers behind adopting electric three-wheelers is critical in promoting greener transport solutions.

METHODS: The research applied the Push-Pull-Mooring framework to analyze the influence of various factors on Switching Intentions. Data were collected through snowball sampling from 457 respondents involved in three-wheeler transport systems. Partial least squares structural equation modeling was employed to test the relationships between the factors and Switching Intentions.

FINDINGS: The results revealed that the push factors of Awareness of Consequences ($\beta = 0.283$, $p < 0.000$) and Environmental Concerns ($\beta = 0.119$, $p < 0.005$), the pull factor of Perceived Technological Usefulness ($\beta = 0.152$, $p < 0.000$), and the mooring factor of Herding Bias ($\beta = 0.341$, $p < 0.000$) significantly influenced Switching Intentions. However, Policy Support ($\beta = 0.007$, $p > 0.829$) and Personal Innovativeness ($\beta = 0.047$, $p > 0.163$) were found to be insignificant. Additionally, Switching Intention strongly predicted actual Use Behaviour ($\beta = 0.697$, $p < 0.000$) and Intention to Recommend electric three-wheelers ($\beta = 0.437$, $p < 0.000$).

CONCLUSION: The study highlighted the importance of environmental awareness and technological perceptions in driving the adoption of electric three-wheelers. These findings offer valuable insights for policymakers, manufacturers, and stakeholders to foster sustainable urban infrastructure development and address environmental challenges by promoting electric three-wheeler adoption. However, the study is limited by its geographic scope and reliance on self-reported data, which may introduce biases. Future research could explore longitudinal studies across diverse urban contexts to assess evolving adoption trends and the long-term impact of policy interventions.

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*Corresponding Author:
Email: *d.sivakumar@klu.ac.in*
Phone: +91-9790973774
ORCID: 0000-0001-5228-0145

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INTRODUCTION

Adopting energy-efficient and clean fuel vehicles has become increasingly critical in addressing environmental challenges. In urban management, the transition to sustainable transportation systems is paramount for reducing urban air pollution and promoting ecological balance. Electric Vehicles (EVs) offer a promising solution to reducing air pollution, a significant environmental threat posed by the reliance on fossil fuels. Integrating EVs into urban transportation systems marks a pivotal step toward enhancing urban sustainability while reducing fossil fuel dependency. The shift towards EVs represents a pivotal step in mitigating the adverse effects of fossil fuel emissions and promoting environmental sustainability. Recent data from the Indian EV market outlook reveals that EV sales surged by 40% to 1.75 million units in 2024 as more people adopt eco-friendly alternatives (Sakena, *et al.,* 2024; Singh *et al*., 2023). Early 2024 saw a 16% uptick in EV registrations, signaling a strong move toward sustainable transport, especially among younger users who are quick to embrace new technologies (Goel, *et al.,* 2021). Government bodies, consumers, and manufacturers are jointly fostering EV adoption throughout India (Singh *et al.,* 2024). India, one of the youngest large countries globally, with a median age of 28 years, positions its substantial youth population as the key driver of the shift toward electric mobility. The increasing engagement of young consumers in adopting EVs reflects an openness to innovative technologies and a strong commitment to sustainability. A report by the Indian Ministry of Transport highlighted that urban areas like Delhi and Mumbai are undergoing rapid transitions to sustainable transportation, driven by concerns about air pollution. The younger generation, motivated by technological advancements, plays a pivotal role in promoting green transportation across the country. Despite the growing shift towards EVs, not all consumers are eager to adopt them. Many still feel hesitant, particularly in a developing country like India, where concerns linger about whether the infrastructure and physical environment are prepared to support EVs effectively. Urban centers face specific challenges such as inadequate charging infrastructure and congested traffic conditions, necessitating strategic urban planning to facilitate EV adoption. This hesitation stems from various reasons, such as limited awareness, higher purchase costs, and the scarcity of nearby charging stations (Azarnoosh *et al*., 2024). These uncertainties surrounding the decision to transition to EVs highlight the need for research to better understand the factors influencing EV adoption. Although past research has extensively explored electric four-wheelers and two-wheelers, the majority of studies have taken a broad approach by focusing on EV consumers in general (Guo *et al*., 2024; La Scalia *et al*., 2023). These studies primarily examine factors such as green consumption intentions, consumer behaviour, and socio-demographic characteristics (Davis and Chandrasekar, 2024). Numerous studies indicate that external factors can significantly shape consumers' intention to transition to EVs. However, this impact is feasible only if consumers possess sufficient knowledge about EVs and recognize personal advantages and societal benefits. This study employs the Push-Pull-Mooring (PPM) framework to analyze the determinants of sustainable transitions within urban transportation systems, specifically focusing on electric three-wheelers as a vital mode of urban mobility. This study employs the PPM framework, initially introduced by Moon (1995), to analyze factors driving individuals to transition from one option to another. While earlier research on EVs typically emphasized contextual and situational influences, the PPM framework enables a more comprehensive understanding of why people or organizations choose to shift between products, services, or technologies, as it considers both motivating and restraining forces. While earlier research on EVs typically emphasized contextual and situational influences, the PPM framework enables a more comprehensive understanding of why people or organizations choose to shift between products, services, or technologies, as it considers both motivating and restraining forces (Hsieh, 2023). The knowledge gaps this study intends to cover is the lack of in-depth analysis specific to the adoption of electric three-wheelers within public transportation. Previous research has focused on broader EV usage, whereas this study explores the unique factors influencing this subset, particularly the underutilization of PS structures resulting from inefficiencies and a lack of awareness. Identifying these bottlenecks offers targeted insights for policy improvement, urban management, and sustainable infrastructure development. The study of electric three-wheelers in

urban transportation systems remains underexplored, with significant gaps in the literature. Azfar *et al.,* (2023) examine broader green transport trends but overlook the unique drivers and barriers of electric three-wheeler adoption, particularly in terms of financial constraints and public transport efficiency. Babagolzadeh *et al.,* (2024) focus on multimodal transport but neglect the specific role of electric three-wheelers in reducing emissions in urban areas. Dou and Choi (2024) discuss the effects of government policies on sustainability without addressing their impact on electric three-wheelers, a sector highly sensitive to local regulations. Research by Kumar *et al.,* (2022) on consumer behaviour towards solar water heaters does not account for the practical factors influencing electric three-wheeler adoption, such as the daily operational needs of drivers. Buigues (2017) explores the automotive industry's influence on policy but fails to consider the adoption dynamics of smaller-scale vehicles like electric three-wheelers. La Scalia *et al.,* (2023) optimize sustainability in maritime transport but overlook the potential of electric three-wheelers in urban mobility. These gaps highlight the need for focused research on the specific socio-economic, environmental, and technological factors that drive electric three-wheeler adoption in urban settings. This study aims to enrich the literature on EV usage behaviour by exploring these dynamics. The study aims to analyze the Switching Intention (SI) of electric three-wheelers using the PPM framework and to explore how SI mediates the relationship between influencing factors, usage behaviour, and the IR of such vehicles. In urban transportation systems, electric three-wheelers contribute to quieter, smoother rides with reduced environmental impact, thereby supporting sustainable urban infrastructure development. The research makes significant contributions by identifying six key factors that drive the transition toward electric three-wheelers. Push factors, such as Awareness of Consequences (ACs) and Environmental Concern (EC), highlight the perceived disadvantages of traditional vehicles, while pull factors, including Policy Support (PS), Perceived Usefulness of Technology (PUT), and Herding Bias (HB), emphasize the attractive features of electric three-wheelers. Personal Innovativeness (PI) acts as a mooring factor, bridging individual characteristics with adoption decisions and offering a deeper understanding of the switching process. The adoption of electric three-wheelers further enhances this utility by delivering quieter, smoother rides with reduced jerking, thereby elevating the comfort levels for both drivers and passengers. This transition not only promotes environmental sustainability but also improves accessibility, positioning electric three-wheelers as a practical and eco-friendly mobility solution. Drawing insights from the current literature, this paper examines how PS, PUT, and herd bias impact the intention to shift from fossil-fueled to electric three-wheelers, as well as how SI mediates the relationship between influencing factors and the resulting usage behaviour and IR electric three-wheelers. This study emphasizes the critical role of urban transportation systems and sustainable urban infrastructure in advancing the adoption of electric three-wheelers. By analyzing the driving and restraining factors, this research offers actionable insights for policymakers and urban managers to facilitate the transition to sustainable transportation modes, ultimately contributing to the broader goal of urban environmental management. This study aims to achieve two primary objectives:

(1) To design and empirically evaluate the PPM framework, identifying the critical determinants influencing the intention to switch to electric three-wheelers,

(2) To identify the mediating role of SI in shaping both usage behaviour and recommendation intentions.

These objectives provide a structured basis for exploring the motivations and barriers associated with adopting electric three-wheelers, a sustainable transportation alternative. To achieve these objectives, the research survey was conducted in Kerala state of India, in 2024.

MATERIALS AND METHODS

The study employs the PPM framework to investigate the behavioural shift from fossil-fueled to electric three-wheelers. Key constructs such as ACs, ECs, and PS are examined as push factors driving the shift, while pull factors include perceived usefulness and HB. PI serves as a mooring factor that influences SI. Data collection involves a structured survey targeting drivers of three-wheelers, capturing their attitudes, SIs, usage behaviours, and IR EVs. Statistical analysis is conducted to explore relationships

between these factors, with SI mediating the effects of influencing variables on subsequent behaviour and recommendations.

Hypotheses on factors influencing electric three-wheeler adoption

PPM framework

This research utilizes the PPM framework, grounded in migration theory, to explore the key factors shaping drivers' decisions to transition from conventional vehicles to electric alternatives. The PPM framework categorizes these influences into three groups: push factors, which drive individuals to move away from current choices; pull factors, which attract them toward new opportunities; and mooring factors, which either support or impede the transition (Azfar *et al*., 2023). Within the urban transportation sector, this model effectively explains the dynamics behind drivers switching from traditional fossil-fueled three-wheelers to electric ones. This transition highlights the interplay between individual agency and systemic urban policies in shaping sustainable urban mobility. In this study, push factors such as ECs and ACs act as catalysts, prompting drivers to move away from fossil-fueled three-wheelers. These factors emphasize the role of increased awareness about environmental issues and a desire for more sustainable practices in driving this shift. Meanwhile, pull factors like PS, PUT, and HB encourage drivers to adopt electric three-wheelers. Lastly, the mooring factor, PI, reflects an individual's willingness to embrace new technologies. This trait can either facilitate or hinder the adoption of electric three-wheelers, depending on the person's openness to innovation and adaptability (Ryu and Kim, 2024).

ACs

ACs refer to the knowledge and understanding that an individual has regarding the environmental and social implications of the behaviour (Khare, 2023). Research has shown that when individuals become aware of the negative consequences of fossil fuel consumption and pollution, Individuals are more likely to shift toward environmentally friendly alternatives such as EVs. (Shetty and Rizwana, 2024). For urban transport operators, such awareness is pivotal in fostering collective responsibility and advancing sustainable practices in metropolitan areas. In the context of three-wheeler drivers, the awareness of the negative environmental impacts of fossil-fueled vehicles can push them toward adopting electric three-wheelers. Accordingly, the following hypothesis is proposed for this study.

H1a: ACs are positively linked with SI for electric three-wheelers

H1b: SI mediates the relationship between ACs and UB for electric three-wheelers

H1c: SI mediates the relationship between ACs and IR electric three-wheelers.

EC

EC plays a crucial role in influencing the adoption of EVs, particularly among individuals who are deeply aware of environmental degradation and pollution's harmful effects. Such concerns often motivate individuals to seek eco-friendly alternatives, such as electric three-wheelers, which emit significantly fewer pollutants compared to their fossil-fueled counterparts (Babagolzadeh *et al*., 2024; Si *et al*., 2024; Watson *et al*., 2023). In urban settings, where air quality directly impacts public health and quality of life, drivers' environmental concerns contribute to the broader agenda of sustainable urban management (Ravindran *et al*., 2024). This concern extends beyond individual preferences to societal responsibility, as the choice directly affects urban air quality and public health. Therefore, this study hypothesizes that environmental concern is a key push factor driving SIs among three-wheeler drivers. Therefore, the following hypothesis is proposed:

H2a: Environmental concern is positively linked with SI for electric three-wheelers.

H2b: SI mediates the relationship between environmental concerns and UB for electric three-wheelers.

H2c: SI mediates the relationship between environmental concerns and IR electric three-wheelers.

H7: Environmental concern is positively linked with IR electric three-wheelers.

PS

PS plays a pivotal role in driving the adoption of EVs and other sustainable transportation options. Previous studies highlight that regulations and subsidies are significant factors influencing the transition to green transportation (Daniele *et al*., 2023). Measures such as Carbon Dioxide (CO_2) taxes,

emission limits, and subsidies tailored to promote the use of electric three-wheelers have demonstrated their effectiveness in encouraging adoption (Hoerler *et al*., 2023). Urban policies that integrate incentives for drivers with infrastructure improvements, such as dedicated charging stations, contribute to sustainable urban mobility systems. A well-designed regulatory framework that prioritizes sustainable transportation can foster this shift by making eco-friendly options more accessible and appealing. Additionally, policies aimed at enhancing green transportation infrastructure and implementing measures to improve the overall system have been shown to positively impact individuals' willingness to adopt EVs (Babagolzadeh *et al*., 2024; Sareen and Haque, 2024). Research underscores the importance of tax incentives, subsidies, and policy-driven support in influencing consumer behaviour, thereby encouraging the switch to sustainable alternatives such as electric three-wheelers. The following hypothesis is proposed:

H3a: PS is positively linked with SI for electric three-wheelers.

H3b: SI mediates the relationship between PS and UB for electric three-wheelers.

H3c: SI mediates the relationship between PS and IR electric three-wheelers.

PUT

PUT refers to the extent to which individuals believe that using a specific technology will enhance their performance or effectiveness (Ryu and Kim, 2024). In urban transport systems, this perceived usefulness often translates into better operational efficiency and enhanced livelihood opportunities for drivers. In the context of electric three-wheelers, perceived usefulness plays a critical role in influencing drivers' adoption decisions. These vehicles offer reduced operational costs, enhanced efficiency, and environmental benefits, which are significant motivators. Moreover, digital technologies such as Google Pay and Google Maps further enhance the usability of electric three-wheelers for drivers. Google Pay facilitates cashless transactions, reducing the hassle of handling physical cash and ensuring smoother operations, especially in urban areas (Kampa, 2023). Google Maps aids in navigation, enabling drivers to identify optimal routes, minimize travel time, and enhance customer satisfaction. Together, these technologies not only improve operational efficiency but also help drivers perceive the overall technological ecosystem as beneficial for their livelihood. Accordingly, the following hypothesis was formulated:

H4a: Perceived usefulness is positively linked with SI for electric three-wheelers.

H4b: SI mediates the relationship between perceived usefulness and UB for electric three-wheelers.

H4c: SI mediates the relationship between perceived usefulness and IR electric three-wheelers.

HB

HB refers to the tendency of individuals to follow the actions or decisions of a larger group, often driven by social influence and the desire to conform rather than individual judgment. In the context of electric three-wheelers, HB significantly impacts adoption behaviours among drivers. When early adopters of electric three-wheelers experience benefits such as reduced fuel costs, government incentives, and higher customer preference, the positive outcomes encourage others to follow suit. In urban contexts, the visibility of such success stories, amplified through word-of-mouth and peer influence, fosters a larger shift towards sustainable transportation systems, reducing dependency on fossil fuels (Khan and Fatma, 2023). Social proof, such as seeing peers benefit financially and operationally from adopting the technology, further strengthens the bias. Consequently, HB accelerates the transition to electric three-wheelers, fostering a collective shift toward sustainable transportation solutions among drivers. Accordingly, the following hypothesis was formulated:

H5a: HB is positively linked with SI for electric three-wheelers.

H5b: SI mediates the relationship between HB and UB for electric three-wheelers.

H5c: SI mediates the relationship between HB and IR electric three-wheelers.

PI

PI refers to an individual's willingness to try out new technologies or adopt innovative solutions earlier than others in the social group (Si *et al*., 2024). In the context of electric three-wheelers, PI plays a crucial role in determining adoption behaviour.

Drivers with high PI are more likely to explore the advantages of electric three-wheelers, such as lower maintenance costs, reduced fuel expenses, and access to government incentives, even before these benefits are widely recognized (Rauf *et al*., 2024). These early adopters often act as trendsetters, showcasing the practical and financial feasibility of EVs. In urban areas, this willingness to adopt and integrate innovative technologies such as GPS systems or cashless payment methods improves operational efficiency and modernizes transportation systems. Accordingly, the following hypothesis was proposed.

H6a: PI is positively linked with SI for electric three-wheelers.

H6b: SI mediates the relationship between PI and UB for electric three-wheelers.

H6c: SI mediates the relationship between PI and IR electric three-wheelers.

SI

SI refers to an individual's deliberate decision to transition from one product, service, or technology to another, often driven by perceived benefits, dissatisfaction with the current option, or external influence (Sridevi and Ajith, 2024). A study revealed that technological aspects such as driving range, charging duration, noise levels, acceleration performance, and reliability, along with contextual elements like cost, incentives, and safety features, significantly influence the intention to switch to EVs (Chandel, 2023). These factors collectively shape individuals' perceptions of EVs, impacting the decision-making process (Davis and Joseph, 2024). Technological attributes address functional performance and usability, enhancing confidence in the vehicle's practicality. Furthermore, adopting electric three-wheelers supports sustainable urban infrastructure by reducing emissions and improving air quality. Accordingly, the following hypothesis was proposed.

H8: SI is positively linked with the UB of electric three-wheelers.

H9: SI is positively linked with IR electric three-wheelers.

UB

UB refers to the extent and manner in which individuals engage with and utilize a particular product, service, or technology in their daily lives (Cabellos *et al*., 2024; Ismail and Rasheed, 2024). It reflects the transition from initial adoption to consistent usage, highlighting how effectively the technology integrates into the user's routine (Le *et al*., 2023). In urban settings, the UB of electric three-wheelers directly influences the efficiency and sustainability of urban transportation systems. Understanding UB provides insights into the practical implications of adoption and the sustainability of engagement over time. It also indicates the degree of user satisfaction, adaptation, and reliance on the technology, serving as a key metric for evaluating the success of innovations in meeting user needs and expectations (Sivakumar and Ismail, 2024). Accordingly, the following hypothesis was proposed.

H10: UB is positively linked with IR electric three-wheelers.

IR

IR refers to an individual's willingness to suggest or endorse a product, service, or technology to others, often based on positive experiences or satisfaction (Natarajan *et al*., 2024). This concept reflects not only the user's approval but also the trust and confidence in the offering. In the context of innovative technologies, IR plays a vital role in driving wider adoption through word-of-mouth and peer influence (Obeid *et al*., 2024). When users perceive significant benefits, such as enhanced performance, cost savings, or convenience, individuals are more likely to advocate for the technology, acting as informal brand ambassadors. In urban contexts, such recommendations create a network effect, accelerating the transition to greener transportation options and contributing to sustainable urban infrastructure. IR is therefore a critical outcome variable, capturing the relational and social dimensions of user satisfaction and loyalty.

Research methodology

Research design

This study adopts a quantitative research design, employing the PPM framework to investigate the behavioural transition from fossil-fuel-powered to electric three-wheelers in urban transportation. The PPM framework, grounded in migration theory, categorizes influencing factors into push (environmental concerns and awareness), pull (perceived usefulness and habit), and mooring

(personal innovativeness) components (Azfar *et al.*, 2023). Structuring the research within this framework, the study systematically examines the determinants of adoption and their impact on sustainable urban mobility. A structured survey approach ensures that key behavioural drivers, attitudes, and adoption intentions are quantitatively assessed.

Focus Population

The study focuses on electric three-wheeler drivers operating within Kerala, India's urban transportation ecosystem. The choice of Kerala as the study area is based on its growing emphasis on sustainable transport policies and increasing adoption of electric three-wheelers. The target population includes registered electric three-wheeler drivers, given their direct experience with electric mobility and urban transport infrastructure challenges. Understanding their perspectives provides valuable insights into adoption barriers, technological usefulness, and sustainability factors (Saari *et al*., 2021).

Sampling procedures

A snowball sampling method was employed to recruit participants, ensuring representation from various urban regions across Kerala. Initially, a set of known electric three-wheeler drivers was approached, who then referred other drivers, expanding the participant pool. A total of 457 respondents were recruited, exceeding the minimum sample size requirement for robust statistical analysis. This non-probability sampling approach was chosen due to the relatively niche population of electric three-wheeler users, ensuring adequate coverage of early adopters and those resistant to the transition (Singh *et al*., 2023). The reliance on snowball sampling in this study may introduce bias, as the sample may not fully represent the broader population of electric three-wheeler drivers, particularly those from diverse demographic and geographic backgrounds. This sampling method tends to capture individuals within a network of existing respondents, potentially overlooking key groups who may have different adoption behaviours. Furthermore, while Partial Least Squares Structural Equation Modelling (PLS-SEM) is a robust technique for examining complex relationships, its limitations in terms of generalizability should be acknowledged. PLS-SEM primarily focuses on exploratory analysis and may not provide the level of external validity required for broad generalizations across varied urban settings. A more diverse sampling approach and a critical discussion of the generalizability of the findings would strengthen the study's external validity and ensure a more comprehensive understanding of the factors driving electric three-wheeler adoption.

Questionnaire

The questionnaire underwent expert review by professionals in EVs to ensure its language was comprehensible for Kerala's electric three-wheeler drivers and that its format was suitable. Special emphasis was placed on ensuring that the questionnaire captured elements related to sustainable transportation and its implications for urban mobility, aligning with the study's urban management focus (Si *et al*., 2024). The survey was administered in two phases to test the conceptual model. Overall, the research model is shown in (Fig. 1). This conceptual framework (Fig. 1) examines the determinants influencing the adoption of electric three-wheelers (e-rickshaws) within urban transportation systems, leveraging principles from the Theory of Planned Behaviour. The framework illustrates hypothesized relationships among critical constructs. Central to the model is "SI," which quantifies the probability of individuals transitioning from conventional transportation modes to e-rickshaws. This intention is determined by key constructs such as "Environmental Concern" (awareness of ecological consequences), "PUT," "PS," "PI," and "HB" (social influence). These determinants are classified into "Push" (motivational drivers) and "Pull" (facilitating factors), which collectively influence decision-making processes. Furthermore, the model identifies "IR" and "UB" as downstream outcomes of SI, highlighting the role of social influence and behavioural execution in actual adoption (Le *et al*., 2023). This research framework is designed to uncover the critical drivers of e-rickshaw adoption, providing actionable insights to inform policy design and strategic interventions for advancing sustainable urban transportation.

Data collection

In this study, a focus was placed on urban transportation systems, particularly examining the adoption and continued use of electric three-wheelers within the sustainable urban infrastructure of Kerala, India. A total of 800 electric passenger

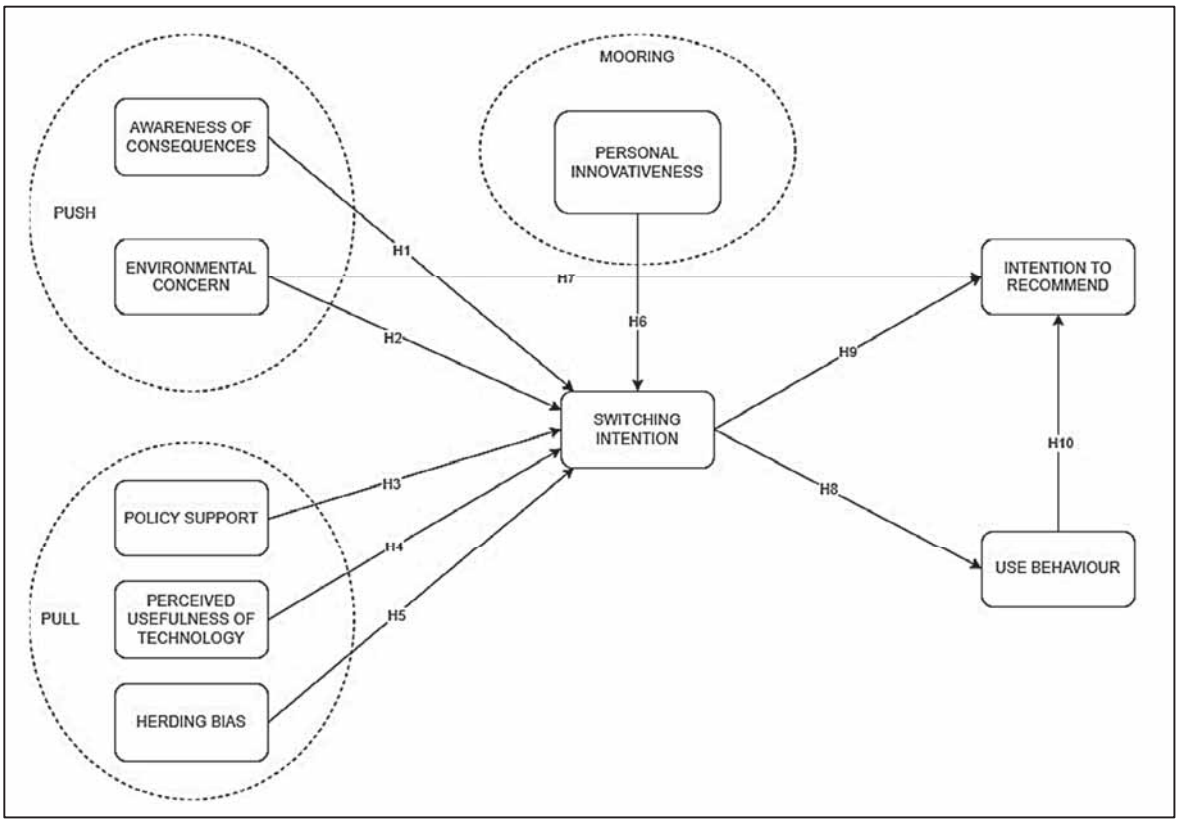

Fig. 1: Research model

three-wheelers were registered across 87 Regional Transport Offices (RTOs) in the state. Registration details and individual data were sourced from the VAHAN Dashboard, part of the Parivahan Sewa portal. This platform, developed by India's Ministry of Road Transport and Highways, aims to digitize and simplify vehicle-related services, making it a dependable data source for research. The data analysis was conducted using Smart Partial Least Squares (SPLS) 4 software, utilizing PLS and Structural Equation Modeling (SEM) to examine relationships within the conceptual model (Kumar *et al.,* 2022). Testing the framework, 457 respondents were recruited using a snowball sampling method, exceeding the minimum sample size requirement. Participation was incentivized with a nominal fee equivalent in value to the minimum fare usually charged for a ride, acknowledging the time and effort involved in completing the survey. These participants provided critical data, enhancing understanding of how electric three-wheelers contribute toward reducing urban pollution, improving public transportation efficiency, and supporting sustainable urban development goals. This research framework ultimately aims at identifying key drivers of e-rickshaw adoption, offering actionable insights informing policy design and strategic interventions promoting sustainable urban transportation.

Statistical analysis

The minimum sample size required for the study was calculated as 109 using G*Power, a well-regarded power analysis tool in behavioural and social sciences (Faul *et al*., 2009). The calculation was based on an a priori analysis with a significance level (α) of 0.05, statistical power (1-β) of 0.99, and a medium effect size (f^2) of 0.15, following the guidelines by Cohen *et al*., (1988). A higher power level of 0.99 was chosen to maximize the likelihood of detecting significant effects. The statistical analysis included correlation and regression techniques to assess relationships within the model, while Cronbach's α was used to measure

Table 1: Demographic distribution of respondents (N=457)

Measure	Item	Frequency	Percentage (%)
Age	18-35	256	56
	35-59	117	26
	Above 60	84	18
Do you have a valid driving license?	Yes	457	100
Have you ever driven an EV, specifically an electric three-wheeler?	Yes	457	100
Do you own an electric three-wheeler?	Yes	457	100
Do you use your electric three-wheeler for public transport services?	Yes	457	100

the reliability of the survey items. Key indicators such as factor loadings, Average Variance Extracted (AVE), Composite Reliability (CR), and the statistical significance, including t-statistics and p-values, were calculated to validate the model's constructs. These metrics ensured robust results, with decisions made based on thresholds for reliability and significance.

RESULTS AND DISCUSSIONS

Measurement models

This study conducted multiple evaluations to analyze the measurement model, focusing on outer loadings, CR, AVE, and discriminant validity, following established standards. In the first phase, demographic details such as age, driving experience, and participation as a public transport electric three-wheeler driver were collected, as shown in Table 1. The second phase focused on gathering information related to the study's constructs, detailed in Table 2.

From Table 1, it may be noted that the demographic distribution of the respondents (N=457) provides insights into their age, driving license status, and electric three-wheeler usage. The majority of respondents (56%) are between 18-35 years old, indicating a younger demographic is more engaged with electric three-wheelers. A smaller proportion of respondents fall into the 35-59 age group (26%), while 18% are above 60 years, reflecting a broad age representation. All participants reported having a valid driving license, suggesting the sample is legally capable of operating vehicles. All respondents have experience driving an electric three-wheeler, own one, and use it for public transport services, underscoring the widespread adoption and integration of electric three-wheelers in urban transportation systems. These demographic characteristics are crucial for understanding the adoption drivers, environmental concerns, and technological perceptions influencing the use of electric three-wheelers in urban settings.

Table 2 presents a comprehensive framework for assessing factors influencing the adoption of electric three-wheelers by categorizing measurement items under latent variables. From Table 2, it could be noted that Push Effects, which encompass awareness of environmental consequences (Singh *et al.,* 2023) and concern for ecological issues (Saari *et al.,* 2021); Pull Effects, which involve government PS (Si *et al.,* 2024) and PUT (Dandiwala *et al.,* 2024); HB, reflecting decisions influenced by others (Jibril *et al.,* 2024); Mooring Effects, emphasizing PI in adopting new technologies (Si *et al.,* 2024); and behavioural constructs such as SI (Liao *et al.,* 2021); UB (Lee *et al.,* 2023) and IR (Natarajan *et al.,* 2024). Each variable is measured through specific indicators, with items reflecting attitudes, behaviours, or perceptions, such as environmental awareness, government policies, and willingness to recommend electric three-wheelers. The measurement items are supported by references to prior studies, ensuring reliability and validity in understanding user behaviour and motivations for transitioning to sustainable transportation solutions. A five-point Likert scale, ranging from "Strongly Disagree" (1) to "Strongly agree" (5), was used to evaluate the responses. The factor loadings for all items, as shown in Table 3, met the inter-item reliability criterion with a minimum threshold of 0.70 (Si *et al.,* 2024). Convergent validity was assessed using the AVE, with all values exceeding the required threshold of 0.50 (Sukhov *et al.,* 2023). Internal consistency was further evaluated through CR, which met the acceptable benchmark of 0.70. The measurement model analysis confirmed that all constructs demonstrated strong reliability and validity. Specifically, constructs like ACs (α = 0.847, AVE = 0.686, CR = 0.848), SI (α = 0.819, CR = 0.820), and IR (α = 0.845, CR = 0.850) showed particularly high

Table 2: Measurement items

Latent variable		Indicators	Items	References
Push effects	ACs	AC1	Conventional three-wheelers contribute to environmental damage.	(Singh *et al*., 2023)
		AC2	Exhaustion of fossil fuels is a problem	
		AC3	Driving conventional three-wheelers affects global warming	
		AC4	Global warming is a problem for society	
	EC	EC1	Generally speaking, how concerned are you about environmental issues	(Saari *et al*., 2021)
		EC2	We worry too much about the future of the environment and not enough about prices and jobs	
		EC3	People worry too much about human progress harming the environment.	
Pull effects	PS	PS1	The government has introduced policies to clarify the legalities of electric three-wheelers	(Si *et al*., 2024)
		PS2	The government formulates policies to guide the development of the electric three-wheelers	
		PS3	The government supports the development of related enterprises	
	PUT	PUT1	Using AI-based technology could help me better understand my travel conditions.	(Dandiwala *et al*., 2024)
		PUT2	I think using technology could help me improve my driving.	
		PUT3	On the whole, I think it is useful to use AI technology	
	HB	H1	I always take opinions based on others' opinions	(Jibril *et al.,* 2024)
		H2	I just follow what the majority of people do	
		H3	I often buy things after seeing others buy them	
Mooring effect	PI	PI1	I like to try new things/technologies	(Si *et al*., 2024)
		PI2	I might be the first person around me to try new things/technologies	
		PI3	If I hear about new things/technology, I would like to try it out	
		PI4	Although trying new things/technologies takes time and energy, I am willing to do it	
	SI	SI1	I am considering switching to an electric three-wheeler	(Liao *et al*., 2021)
		SI2	I intend to switch to electric three-wheelers	
		SI3	I have made up my mind to switch to electric three-wheelers in the future	
	UB	UB1	I have used an electric three-wheeler in the past six months.	(Le *et al*., 2023)
		UB2	I have used an electric three-wheeler in the past six months to make personal purchases.	
		UB3	The outcome of the electric three-wheeler is better	
	IR	IR1	I would like to recommend an electric three-wheeler to other three-wheeler users	(Natarajan *et al*., 2024)
		IR2	I would like to share my electric three-wheeler experience with others	
		IR3	I would like to encourage others to use an electric three-wheeler	

reliability, indicating strong respondent awareness of environmental issues and readiness to adopt and recommend electric three-wheelers. To ensure discriminant validity, the Heterotrait-Monotrait (HTMT) ratio analysis was performed, where all values remained below the threshold of 0.85, confirming sufficient discriminant validity (Sukhov *et al.,* 2023). Overall, the findings demonstrate that the measurement model is robust, with reliable and valid constructs that provide a solid foundation for further analysis of user behaviour and adoption patterns. The results summarized in Table 4 demonstrate that the square root of the AVE for each construct exceeds its correlations with other constructs, confirming the discriminant validity of the model. This validation process affirms the reliability and validity of the

Table 3: Measurement model analysis

Construct	Cronbach's α	Indicators	Factor loading	AVE	CR
ACs	0.847	AC1	0.803	0.686	0.848
		AC2	0.873		
		AC3	0.807		
		AC4	0.829		
EC	0.777	EC1	0.846	0.689	0.790
		EC2	0.836		
		EC3	0.808		
PS	0.76	PS1	0.766	0.675	0.773
		PS2	0.869		
		PS3	0.826		
PUT	0.741	PUT1	0.785	0.660	0.746
		PUT2	0.856		
		PUT3	0.793		
HB	0.778	HB1	0.836	0.692	0.796
		HB2	0.879		
		HB3	0.776		
PI	0.809	PI1	0.794	0.635	0.818
		PI2	0.733		
		PI3	0.838		
		PI4	0.818		
SI	0.819	SI1	0.861	0.735	0.820
		SI2	0.878		
		SI3	0.831		
UB	0.831	UB1	0.883	0.748	0.831
		UB2	0.840		
		UB3	0.871		
IR	0.845	IR1	0.907	0.763	0.850
		IR2	0.881		
		IR3	0.832		

Table 4: Discriminant validity

Construct	ACs	EC	HB	IR	PUT	PI	PS	SI	UB
ACs	-	-	-	-	-	-	-	-	-
EC	0.563	-	-	-	-	-	-	-	-
HB	0.691	0.744	-	-	-	-	-	-	-
IR	0.594	0.691	0.801	-	-	-	-	-	-
PUT	0.366	0.589	0.592	0.451	-	-	-	-	-
PI	0.593	0.493	0.612	0.540	0.573	-	-	-	-
PS	0.293	0.389	0.471	0.467	0.331	0.341	-	-	-
SI	0.715	0.654	0.822	0.758	0.600	0.573	0.359	-	-
UB	0.709	0.558	0.844	0.822	0.520	0.613	0.471	0.841	-

measurement model, ensuring its robustness for further analysis (Shabbir Husain, 2020). Table 4 shows the discriminant validity analysis, where the diagonal values represent the square root of AVE for each construct, while the off-diagonal elements indicate the correlations between constructs. Discriminant validity is confirmed when the square root of AVE for each construct exceeds its correlations with other constructs, which all constructs meet in this analysis (Rauf *et al*., 2024). Awareness of Consequences, with a square root of AVE value of 0.803, exceeds its correlation with EC (0.563), confirming the distinction between these constructs (Ravindran *et al*., 2024). The strongest correlation occurs between HB and SI (0.822), indicating a significant relationship between social influence and the intention to adopt electric three-wheelers (Ryu and Kim, 2024). In contrast, PS shows weaker correlations with other constructs, suggesting that while important, it has a less direct influence on user behaviour compared

to technological usefulness or social influence (Saari *et al*., 2021). The analysis ultimately supports the robustness of the measurement model, highlighting that environmental concerns, technological perceptions, social influences, and PS are distinct yet interrelated factors affecting the adoption of electric three-wheelers in urban transportation systems (Sareen and Haque, 2024; La Scalia *et al*., 2023; Sheldon and Dua, 2019).

Structural model

The structural model analysis in this study explores the relationships between various factors influencing the adoption of electric three-wheelers. It examines key drivers such as environmental concerns, technological usefulness, and social influences in shaping user behaviour and intention. Table 5 presents the results of the hypotheses tested, showing the relationships and significance levels between key factors influencing the adoption of electric three-wheelers, including environmental concerns, technological usefulness, social influence, and user behaviour.

Table 5 presents the results of the hypotheses tested in the study, providing insights into the relationships between various factors influencing the adoption of electric three-wheelers. The analysis shows that several factors significantly impact SI, including ACs, EC, HB, PUT, and SI itself. Specifically, ACs have a positive influence on SI (0.283), EC significantly affects IR (0.269), HB impacts SI (0.341), and PUT influences SI (0.152), all with p-values less than 0.05. However, PI and PS did not show significant effects, with their p-values being 0.163 and 0.829, respectively. Additionally, SI strongly affects both IR (0.184) and UB (0.697), emphasizing the importance of user behaviour in the adoption process. Finally, UB positively impacts IR electric three-wheelers (0.437), supporting the relationship between actual usage and advocacy. Overall, these findings suggest that environmental concerns, technological perceptions, social influences, and user behaviours are critical drivers in shaping the adoption of electric three-wheelers, with some factors, such as PS and PI, requiring further exploration to fully understand their impact. Detailed mediation results are presented in Table 6, with Fig. 2 providing a visual representation of the conceptual model outcomes. Fig. 3 shows the graphical representation of the hypothesis testing results as a bar graph. The bars represent the path coefficients for each hypothesis, with green indicating "Supported" hypotheses and red indicating "Not Supported" hypotheses. Fig. 4 shows the graphical representation of the mediating hypotheses testing results, where the path coefficients are plotted as horizontal bars. Table 6 and Fig. 2 both present the mediation effects in the conceptual model, showing significant relationships influencing electric three-wheeler adoption.

Table 6 and Fig. 2 show that the mediation pathways from ACs, environmental concern, HB, and PUT through SI to UB demonstrate strong effects. Specifically, the ACs, SI, and UB pathways have a significant effect of 0.197 with a critical value of 7.100, confirming the robust mediation. Environmental concern also exhibits a significant indirect effect on UB via SI of 0.083 with a critical value of 2.946, while HB of 0.237 with a critical value of 4.953 and PUT of

Table 5: Results of hypotheses tested

Construct	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Decision
AC → SI	0.283	0.286	0.039	7.272	0.000	Supported
EC → IR	0.269	0.272	0.045	5.994	0.000	Supported
EC → SI	0.119	0.117	0.043	2.790	0.005	Supported
HB → SI	0.341	0.340	0.058	5.887	0.000	Supported
PUT → SI	0.152	0.152	0.037	4.069	0.000	Supported
PI → SI	0.047	0.047	0.033	1.397	0.163	Not Supported
PS → SI	0.007	0.009	0.031	0.215	0.829	Not Supported
SI → IR	0.184	0.183	0.041	4.536	0.000	Supported
SI → UB	0.697	0.698	0.031	22.380	0.000	Supported
UB → IR	0.437	0.436	0.043	10.061	0.000	Supported

Table 6: Mediation result

Construct	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Decision
AC→ SI → UB	0.197	0.199	0.028	7.100	0.000	Supported
PI→ SI → IR	0.009	0.009	0.006	1.336	0.182	Not Supported
EC →SI → UB	0.083	0.081	0.028	2.946	0.003	Supported
PS → SI → IR	0.001	0.002	0.006	0.210	0.834	Not Supported
SI → UB → IR	0.305	0.304	0.032	9.508	0.000	Supported
HB → SI → UB	0.237	0.238	0.048	4.953	0.000	Supported
PUT→ SI → UB	0.106	0.106	0.027	3.949	0.000	Supported
PI→ SI → UB	0.032	0.033	0.023	1.409	0.159	Not Supported
PS → SI → UB	0.005	0.007	0.022	0.215	0.830	Not Supported
EC→ SI → UB→ IR	0.036	0.035	0.013	2.783	0.005	Supported
AC→ SI → UB→ IR	0.086	0.087	0.015	5.666	0.000	Supported
PS→ SI → UB→ IR	0.002	0.003	0.010	0.214	0.831	Not Supported
HB→ SI → UB→ IR	0.104	0.104	0.022	4.652	0.000	Supported
PI→ SI → UB→ IR	0.014	0.014	0.010	1.394	0.163	Not Supported
PUT→ SI → UB→ IR	0.046	0.046	0.012	3.290	0.000	Supported
AC→ SI →IR	0.052	0.052	0.013	3.956	0.000	Supported
EC→ SI → IR	0.022	0.021	0.009	2.459	0.014	Supported
HB→ SI → IR	0.063	0.063	0.019	3.290	0.001	Supported
PUT→ SI → IR	0.028	0.028	0.009	3.226	0.001	Supported

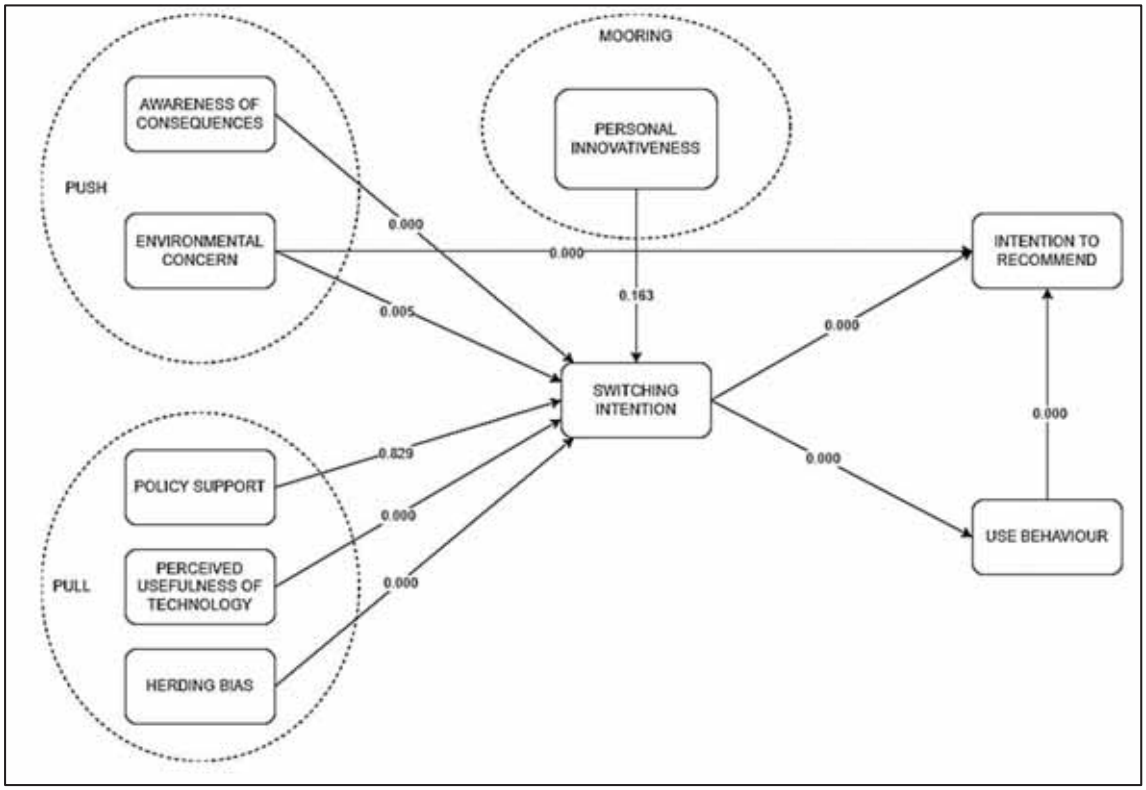

Fig. 2: Results of the conceptual model

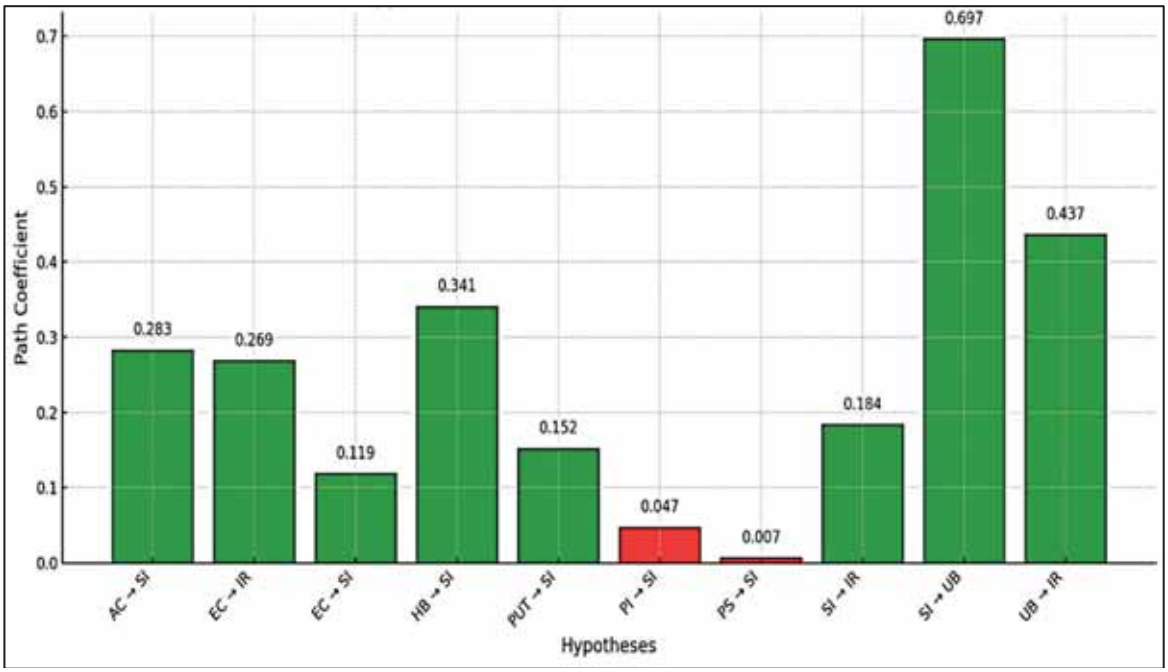

Fig. 3: Graphical representation of the hypotheses testing results as a bar graph

0.106 with a critical value of 3.949 show significant mediation. The relationship between SI and UB, as well as SI and IR, is also significant, with critical values of 22.380 and 9.508, respectively. Conversely, PI and PS show non-significant mediation effects with critical values of 1.336 and 0.215, respectively, indicating a minimal role in adoption behaviour. Both Table 6 and Fig. 2 collectively highlight the pivotal role of environmental concern, social influence, and technology perceptions in driving electric three-wheeler adoption, with mediation primarily occurring through SI. Fig. 3 reveals that the strongest relationships are between SI and UB (0.697) and UB and IR (0.437), indicating a significant impact between these variables. HB also substantially influences SI (0.341). Moderate relationships include AC to SI (0.283) and EC to IR (0.269), while PI and PS show negligible impacts on SI with coefficients of 0.047 and 0.007, respectively. These insights are crucial for prioritizing factors that drive the study outcomes and can help optimize strategies to focus on impactful variables. Fig. 4 displays the path coefficients for various mediating hypotheses. The strongest relationships are SI to UB (0.305) and HB to SI to UB (0.237), indicating significant impacts. Moderate relationships include PUT to SI to UB (0.106) and AC to SI to UB (0.197). Lower relationships, such as HB to SI to IR (0.063) and AC to SI to IR (0.052), also show positive impacts. Notably, PS to SI to UB to IR (-0.032) and PI to SI to UB to IR (-0.014) have negative coefficients, indicating negligible or negative impacts. These insights highlight the importance of focusing on SI and UB for meaningful study outcomes while deprioritizing less impactful variables.

Interpretation of results

This study examines the factors driving electric three-wheeler adoption in urban transportation, focusing on demographic patterns, push and pull effects, and social influences. It compares the findings with previous studies, highlighting key similarities and differences in motivations and barriers. The insights provide valuable recommendations for enhancing EV adoption and promoting sustainable urban mobility.

Demographic distribution and adoption of electric three-wheelers

The study reveals a clear demographic pattern, with younger age groups, particularly those between 18-35 years, being the predominant

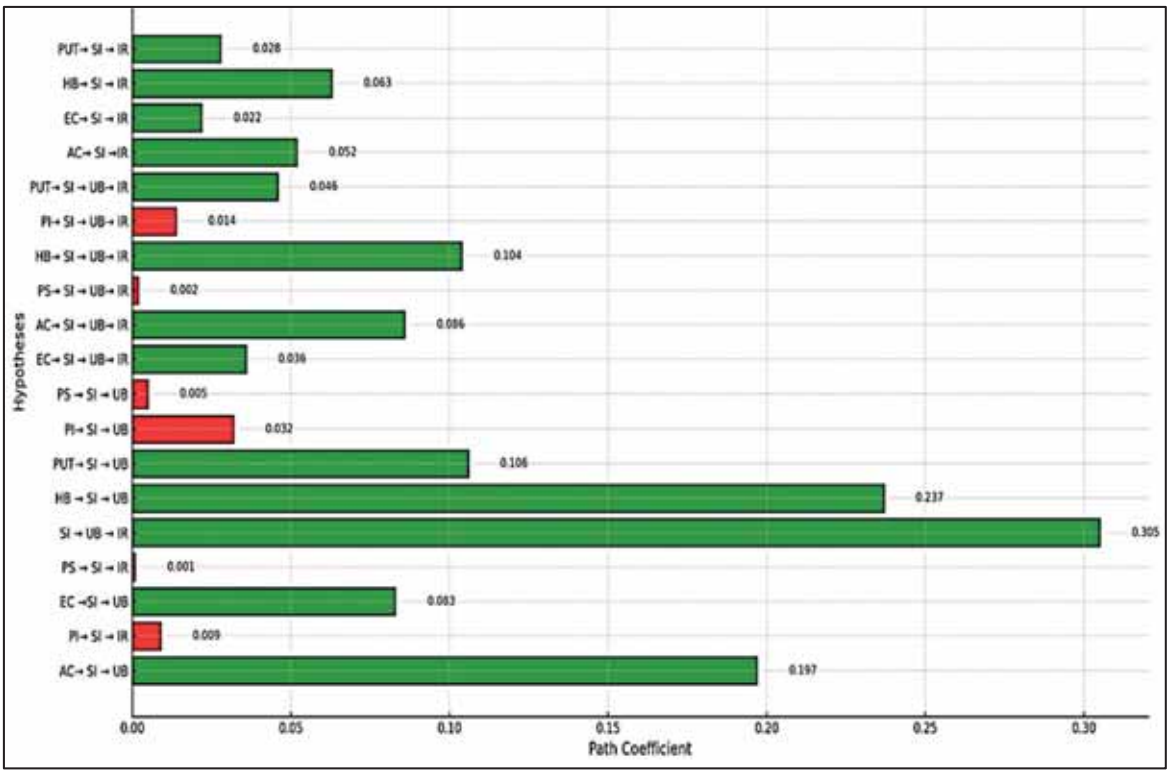

Fig. 4: Graphical representation of the mediating hypotheses testing results as a bar graph

adopters of electric three-wheelers. A notable 56% of respondents within this age group show a higher propensity to engage with sustainable transportation options. This supports the findings by Chandel (2023), who indicated that younger individuals are generally more environmentally conscious and open to adopting new technologies like EVs (EVs). The study also found that respondents universally possessed a valid driving license and had prior experience with electric three-wheelers, further highlighting the normalization of electric three-wheelers in urban transportation systems, particularly for public transport. The alignment with Azfar *et al*., (2023) is evident here, as younger individuals are more likely to embrace environmentally friendly alternatives, especially following the post-COVID-19 shift toward sustainability. This demographic's adaptability to new transportation options underlines the importance of targeting younger generations when promoting electric three-wheelers.

Factor analysis: Push, Pull, Herding, and Mooring effects

The study identifies Push and pull effects, alongside Herding and Mooring effects, as significant factors influencing the intention to switch to electric three-wheelers. Push Effects refer to environmental awareness and ecological concerns, which were found to strongly influence the intention to adopt electric three-wheelers. This aligns with Chu *et al*., (2018), who emphasized the role of environmental concerns in EV adoption globally. Awareness of the consequences of traditional fuel-powered vehicles on air quality and greenhouse gas emissions emerged as a crucial factor, with a significant influence on drivers' intentions (β = 0.283, P = 0.000). This highlights that drivers are becoming more conscious of their environmental impact, reinforcing the need for targeted communication that emphasizes the ecological benefits of switching to EVs. Policymakers and manufacturers can use this awareness to

encourage adoption by focusing on messages that underscore the positive environmental impact, such as cleaner air and reduced pollution, which can motivate environmentally-conscious drivers (Babagolzadeh *et al.,* 2024). However, while environmental concern is positively associated with SI (β = 0.119, P = 0.005), the study also reveals that it does not serve as the primary motivator. This aligns with studies indicating that practical considerations often outweigh ecological motivations in urban transportation (Dou and Choi, 2021; Sovacool and Axsen, 2018). Drivers, particularly autorickshaw drivers, face financial constraints that require prioritizing reliability, affordable fuel, and maintenance, making them less likely to make decisions based purely on environmental concerns. This insight suggests that although environmental sustainability is a key factor, financial practicality remains central to the decision-making process for many drivers, as they depend on their vehicles for daily income. PS, like subsidized training, parking benefits, and insurance reductions, was found to have minimal impact on SI (β = 0.007, P = 0.829). This result echoes previous studies suggesting that government incentives may not be as effective in directly influencing individual adoption behaviours (Allahmoradi *et al*., 2022). While these incentives have been shown to benefit manufacturers and retailers, their impact on drivers is limited, possibly due to factors like lack of awareness, bureaucratic complexity, or ineffective implementation. This insight highlights the need for better communication of these benefits and more efficient execution of policy measures to effectively encourage the adoption of electric three-wheelers. Pull Effects, particularly the PUT like Google Maps and Google Pay, also play a significant role in influencing adoption (β = 0.152, P = 0.000). These technologies contribute to operational efficiency by enhancing route optimization and simplifying financial transactions. Educational initiatives that demonstrate how such technologies seamlessly integrate with EVs can help alleviate barriers to adoption. By emphasizing the practical benefits of these technologies, stakeholders can enhance drivers' confidence in adopting electric three-wheelers. HB was another significant factor in driving adoption (β = 0.341, P = 0.000), underscoring the power of social influence in shaping decisions. The study finds that drivers are highly influenced by the actions of their peers, as they trust recommendations and behaviours within their communities. This is consistent with Davis and Joseph (2024), who found that social influence plays a crucial role in EV adoption. Leveraging this by amplifying success stories and encouraging drivers to share their positive experiences can facilitate broader adoption, particularly in tightly-knit driver communities. In contrast, Mooring Effects, such as PI, were found not to significantly influence SI (β = 0.047, P = 0.163). This contrasts with the findings by Chandel (2023), which highlighted the role of PI in EV adoption. This divergence could be explained by the fact that many of the respondents were already familiar with electric three-wheelers, reducing their desire to experiment with new technologies. This suggests that external factors, particularly practical and social considerations, are more influential in driving adoption than the individual inclination toward innovation.

Respondents' perspectives on latent variables

Beyond demographic profiling, this study examines respondents' perspectives on latent variables such as push, pull, herding, and mooring effects, which influence the adoption of electric three-wheelers. The frequency analysis of these latent variables reveals that 56% of respondents in the 18-35 age group exhibit a high inclination toward sustainable transportation, aligning with previous studies (Chandel, 2023). Among the Push effects, EC significantly influences the shift to electric three-wheelers, with β = 0.283, P = 0.000, highlighting a strong awareness of ecological consequences. However, while EC positively correlates with SI (β = 0.119, P = 0.005), it is not the primary motivator for adoption. In the Pull Effects, PUT, including tools like Google Maps and Google Pay, plays a critical role in facilitating adoption (β = 0.152, P = 0.000). HB emerges as one of the strongest factors influencing social acceptance (β = 0.341, P = 0.000), suggesting that peer influence is essential in decision-making. Conversely, PS has a minimal impact on adoption (β = 0.007, P = 0.829), implying that government incentives alone may not be sufficient to drive behavioural change. PI, classified under Mooring Effects, does not significantly affect SI (β = 0.047, P = 0.163), suggesting that familiarity with electric three-wheelers reduces the role of individual innovation in adoption decisions. These results validate the

theoretical framework by confirming that SI is the key mediator in adoption, with environmental concern, social influence, and technological usefulness being the strongest predictors of sustainable urban transportation adoption.

Measurement model validation

The robustness of the measurement model was confirmed through factor loadings, convergent validity, and discriminant validity tests. The constructs, including ACs, SI, and IR, satisfied the necessary reliability and validity standards, ensuring the robustness of the study's framework. The AVE and CR scores were consistent with previous research (Si *et al*., 2024), confirming that the constructs are reliable. The HTMT ratio analysis further validated discriminant validity, ensuring that each construct was distinct from the others, which is essential for drawing accurate conclusions from the data (Sukhov *et al*., 2023).

Structural model and hypothesis testing

The structural model analysis confirmed that SI is a significant mediator between both UB and IR, supporting the theoretical framework of the study. This mediation effect aligns with previous research (Dash 2021), which identified SI as a key predictor of EV adoption and recommendations. While PS and PI did not significantly influence SI, it underscores the need for further research into how these factors interact with user behaviour. The findings also demonstrate that push factors such as environmental concern and awareness, along with pull factors like technological usefulness and social influence, have a strong relationship with SI. This supports the hypotheses of the study, confirming that environmental and technological perceptions are important drivers of adoption (Huang and Ge, 2019).

Mediation effects

The study's mediation analysis shows that environmental concern, HB, and perceived technological usefulness play a significant role in predicting UB through SI. This aligns with findings from Davis and Chandrasekar (2024), highlighting the importance of SI for the continued use of EVs. The study also supports previous research, showing that user behaviour strongly influences the adoption of green technologies, reinforcing the significance of SI as a predictor for actual usage and willingness to recommend EVs (Ryu and Kim (2024).

Path coefficients and inferential insights

Figures 3 and 4 reveal that SI (β = 0.697) and UB (β = 0.437) are the strongest predictors of IR. This suggests that individuals who decide to switch to electric three-wheelers are more likely to adopt and recommend them to others. This supports Azfar *et al*., (2023), who noted that user advocacy is crucial for scaling green transportation solutions. Conversely, the negligible effects of PI and PS emphasize the greater influence of social influence and environmental awareness in driving adoption. This insight suggests that future efforts should focus more on leveraging social proof and environmental messages to promote the adoption of electric three-wheelers. This study emphasizes the primary drivers of electric three-wheeler adoption, namely environmental concern, technological perceptions, and social influence. While government policies and PI remain relevant, their direct impact on SI is less pronounced. The mediation effects further emphasize the critical role of SI and UB in fostering adoption. These findings contribute to shaping strategies aimed at promoting electric three-wheelers, particularly by focusing on environmental concerns, enhancing technological integration, and leveraging user advocacy to strengthen adoption and create sustainable urban transportation systems.

Theoretical implications

The theoretical contributions of this study encompass several critical dimensions. It responds to the pressing need for in-depth research on EVs, particularly within the context of emerging green technologies. Aligning with the growing academic interest in understanding the motivations behind switching to electric three-wheelers, the study introduces new perspectives specific to Kerala, India. Kerala's proactive stance on sustainable transport aligns with urban management and smart city objectives, reinforcing the significance of this research. The transition from conventional fuel-based to electric three-wheelers in such regions offers notable advantages, including improved cost efficiency and enhanced user comfort, emphasizing the importance of uncovering the factors driving this behavioural shift. Existing studies predominantly explore the adoption of EVs in a general context,

with limited attention to the niche segment of public three-wheeler passenger vehicles. This research addresses this gap by providing an in-depth analysis of the elements influencing the decision to adopt electric three-wheelers, identifying unique variables specific to this domain. Unlike prior work that focuses on broader categories of EV usage, this study narrows its lens to a critical subset of public transportation, enriching the literature with specialized insights into urban transportation systems and sustainable urban infrastructure. This research distinguishes itself by exploring the nuanced interplay of these factors, revealing that while PS structures exist, such structures remain underutilized due to implementation inefficiencies and a lack of awareness among drivers. Identifying these bottlenecks sheds light on critical areas for policy improvement, offering actionable insights that can enhance the effectiveness of such measures. These findings highlight the need for improved urban management and public health strategies to address procedural complexities and limited access to reliable infrastructure, factors that hinder the adoption of EVs. The study provides a comprehensive understanding of the motivations and barriers associated with switching to electric three-wheelers. It addresses key drivers, such as cost savings and reduced environmental impact, and delves into the inhibitors that slow down the transition, such as procedural complexities and limited access to reliable infrastructure. This approach addresses the primary research question and lays the foundation for future exploration of strategies to promote the adoption of green transportation solutions, contributing to both theoretical advancements and practical applications in the field. This research effectively addresses RQ1, RQ2, and RQ3 by elucidating the factors influencing drivers' intentions to continue using electric three-wheelers and providing insights into decision-making dynamics.

Practical implications

This study offers critical implications for governments and policymakers aiming to encourage a transition toward green transportation. The results confirm that both push and pull factors significantly shape individuals' willingness to shift. Push factors, such as environmental concern and ACs, influence people who understand the harmful impact of environmental pollution on health and well-being, leading them to adopt eco-friendly transportation options. Pull factors, including PS, regulations, and incentives, complement this by creating favorable conditions for sustainable urban mobility. Public education is essential for strengthening these drivers. Campaigns can raise awareness about how individual travel choices affect the environment, emphasizing the benefits of sustainable transportation in enhancing urban health and ecology. Promoting low-carbon practices through educational programs can further reinforce this shift. Policy efforts must address barriers related to traditional fuel-based three-wheelers while communicating the advantages of green transportation. Effective policies must balance deterrents and incentives to foster sustainable behaviour change, ensuring that these measures translate into action. Transportation operators must focus on delivering high-quality services, ensuring user trust and long-term engagement. Enhancing reliability, comfort, and accessibility motivates individuals to continue using green transportation. Manufacturers also have a vital role, as improving the user experience through awareness initiatives and training programs empowers drivers with the skills needed to confidently operate and maintain electric three-wheelers. These efforts not only address operational challenges but also build trust in eco-friendly technologies. Collaboration among policymakers, transportation operators, and government agencies is vital for creating ecosystems that encourage sustainable mobility. Coordinated efforts contribute to environmental protection and public health, paving the way for a more sustainable and environmentally conscious transportation system (Singh *et al.,* 2023). The practical implications can be translated into concrete policy recommendations, such as reducing the upfront costs of electric three-wheelers, expanding charging infrastructure, and offering targeted financial incentives. Challenges such as financial constraints, limited resources, and resistance from established stakeholders, like fossil-fuel vehicle manufacturers and drivers, may impede implementation. Policymakers should consider phased approaches, leveraging public-private partnerships, and collaborating with stakeholders to address these barriers. Ongoing policy evaluation and adjustments based on stakeholder feedback will be essential to ensure the successful implementation and long-term sustainability of the recommendations.

The study highlights the insignificant impact of PS on the adoption of electric three-wheelers, suggesting that government incentives and interventions may not be as effective in influencing adoption behaviours as initially expected. Policymakers should consider refining the design and execution of PS mechanisms. Simplifying bureaucratic processes, improving awareness and communication of available incentives, and addressing the specific barriers drivers encounter, such as high initial costs, limited charging infrastructure, and maintenance concerns, could enhance the effectiveness of these policies. Integrating PS with targeted educational campaigns and community-driven initiatives may increase the perceived value of incentives. Focusing on the practical needs and concerns of electric three-wheeler drivers could improve the success of efforts aimed at promoting the adoption of sustainable urban transportation solutions.

Recommendations

Enhancing the adoption of electric three-wheelers in urban transportation requires addressing present and future challenges. Public awareness and consumer trust play a crucial role, as environmental knowledge and risk perception influence sustainable behaviour (Saari *et al.*, 2021), while effective incentive structures encourage adoption (Joshi and Rahman, 2017). Strengthening technological infrastructure is essential, considering information privacy concerns and electricity usage habits (Ryu and Kim, 2024), alongside financial incentives and regulatory frameworks that support adoption (Saxena *et al.*, 2024). Urban planning must overcome land development barriers to ensure efficient charging infrastructure integration (Sareen and Haque, 2024), aligning with green transport initiatives for sustainability (Malik *et al.*, 2018). Leveraging emerging technologies and adoption models can provide insights into behavioural patterns and user-centric solutions (Natarajan *et al.*, 2024; Kampa, 2023).

Future scope

This study has limitations that offer directions for future research. It captures drivers' intentions at a single point in time. Future research could adopt a longitudinal approach, observing drivers' adoption and sustained use of electric autorickshaws over an extended period. This approach would reveal insights gained after significant experience with the product, providing a deeper understanding of the factors influencing the sustainability of electric autorickshaw usage in urban environments, particularly in urban mobility systems. The study focuses exclusively on current users of electric autorickshaws. Expanding the scope to include non-adopters could uncover factors that discourage switching, offering a more comprehensive perspective on urban transportation systems. Understanding these barriers would help address limitations in the uptake of eco-friendly transportation and contribute to urban management and smart city development. The research is centered on Kerala, an Indian state with unique contextual factors. While adoption patterns in Kerala may share similarities with other regions, examining adoption rates across states and countries with different cultural contexts, infrastructure availability, and PS would highlight how these factors shape electric autorickshaw adoption in diverse settings. The study primarily uses quantitative data. Incorporating qualitative methods in future research would provide a more nuanced view of drivers' decision-making processes and experiences, yielding richer insights into motivations and challenges surrounding adoption. Addressing these limitations will contribute to a more comprehensive understanding of the factors shaping both the adoption and sustained use of electric autorickshaws in urban mobility systems.

CONCLUSIONS

India's significant contribution to global air pollution, as highlighted by the World Air Quality Report, emphasizes the critical need for sustainable transport solutions. Transportation remains a major contributor to emissions, prompting policymakers to prioritize strategies aimed at reducing air pollution. In alignment with global zero-emission mobility goals, EVs have emerged as a pivotal focus in these efforts. Among these, electric autorickshaws play a vital role in the public transport landscape of a developing country like India, supported by targeted government initiatives promoting their adoption. EVs, especially electric three-wheelers, align with sustainable urban infrastructure goals by offering an eco-friendly, low-emission alternative to traditional transport modes. While this study focuses on the adoption of electric autorickshaws

in Kerala, India, Kerala's unique socio-economic, cultural, and environmental landscape may limit the broad applicability of these findings. To address this, a comparative contextual analysis is proposed, examining data from regions with similar socio-environmental priorities and transportation patterns, both within India and internationally. By identifying commonalities and contrasts, the findings can be explored to assess the relevance to states and regions that share certain characteristics, while acknowledging areas of divergence. For example, within India, states such as Karnataka, Tamil Nadu, and Maharashtra have emphasized sustainable public transport solutions as part of their environmental strategies. Karnataka's capital, Bengaluru, recently introduced a substantial fleet of electric buses, targeting a 60% reduction in transportation emissions by 2030. Tamil Nadu has enacted policies promoting EV adoption, aiming to register over 1.5 million EVs by 2028. Maharashtra has committed to deploying 25% EVs by 2025, with Mumbai leading initiatives to cut down urban congestion and reduce pollution levels by incorporating more electric options into its public transportation network. Internationally, several regions have integrated three-wheeled vehicles into the public transport systems, with some transitioning to electric variants. In Southeast Asia, countries like Thailand and the Philippines have long relied on three-wheelers, known locally as tuk-tuks and tricycles, respectively, as essential modes of urban transport. Thailand has been actively promoting the adoption of electric tuk-tuks to reduce urban air pollution, with government incentives in place to encourage this shift. Similarly, the Philippines has launched initiatives to replace gasoline-powered tricycles with electric alternatives to combat environmental concerns, backed by government subsidies and partnerships with private enterprises to make the transition more accessible. In Africa, countries such as Kenya and Uganda have seen a rise in the use of three-wheelers, known locally as boda-bodas, for public transportation. Governments in these regions, recognizing the economic and environmental advantages of EVs, are working with international organizations to introduce electric three-wheelers and establish supporting infrastructure. These examples demonstrate that while contexts may vary, the push for sustainable public transport solutions is a shared objective globally, with governments actively supporting the transition through incentives, subsidies, and partnerships. Analyzing these patterns, the goal is to provide insights that, while rooted in Kerala's specific context, may offer valuable lessons for similar regions globally, particularly in urban transport systems and smart city frameworks. The study could have critically addressed limitations, such as the potential bias introduced by snowball sampling, which may affect the generalizability of the findings to a broader population of three-wheeler drivers. A reflection on the challenges in implementing recommendations, including financial constraints and possible resistance from stakeholders like manufacturers or drivers, would have provided a more balanced perspective. A clearer call to action, emphasizing specific policy interventions and the need for collaboration among stakeholders, would have enhanced the practical relevance of the findings for promoting electric three-wheeler adoption in urban transportation systems.

AUTHOR CONTRIBUTIONS

T.D. Pushpam conceptualized and designed the study, developed the methodology, curated the data, conducted formal analysis, and was involved in writing the original draft, reviewing and editing the manuscript, and project administration. T. Chandrasekar contributed to the conceptualization and methodology, provided supervision, and participated in the manuscript's writing, review, and editing. D. Sivakumar contributed to the editing, final corrections, and technical improvement of the manuscript. All authors significantly contributed to the research and manuscript preparation, reviewed the final version, and took responsibility for the work's content and integrity.

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have been instrumental in advancing this research and deepening the understanding of electric autorickshaw adoption trends in Kerala.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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NOMENCLATURE	DEFINITION
%	Percentage
ACs	Awareness of Consequences
AVE	Average Variance Extracted
CO_2	Carbon Dioxide
CR	Composite Reliability
EC	Environment Concern
EV	Electrical Vehicle
EVs	Electrical Vehicles
f^2	Medium effect size
GPS	Global Positioning System
HB	Herding Bias
HTMT	Heterotrait-Monotrait
M	Sample Mean
O	Original Sample
PI	Personal Innovativeness
PLS	Partial Least Squares
PLS-SEM	Partial least squares structural equation modeling
PPM	Push-Pull-Mooring
PS	Policy Support
PUT	Perceived Usefulness of Technology
RTOs	Regional Transport Offices
SEM	Structural Equation Modeling
SI	Switching Intention
SPLS	Smart Partial Least Squares
STDEV	Standard Deviation
UB	Use Behaviour
A	Significance level
B	Beta

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ORIGINAL RESEARCH PAPER

Optimal fire station site selection: A Fuzzy-GIS Multi-Criteria hybrid approach

H. Karbalaie[1,*], F. Izadbin[2]

[1] *Department of RS & GIS, Faculty of Geography, University of Tehran, Tehran, Iran*

[2] *Department of Environmental Planning, Management & Education, Faculty of Environment, University of Tehran, Tehran, Iran*

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ABSTRACT

BACKGROUND AND OBJECTIVES: Cities, with their complex infrastructures and diverse services, require a scientific and principled approach to strategic site selection for service provision. Fire stations represent one of the most essential urban services, and inadequate research and planning for their site selection and distribution in many cities significantly increase risks to urban residents' safety and well-being. District 8 of Karaj faces rapid population growth and urban development, highlighting the urgent need for a strategic expansion of fire stations. This study aimed to propose a novel approach to assist in the optimal site selection of fire stations in this area.

METHODS: This study employed a novel hybrid method combining the Stepwise Weight Assessment Ratio Analysis method and Fuzzy logic with ArcGIS techniques. This integration aimed to minimize ambiguity in weighting criteria and improve the accuracy of site selection decisions. The 11 criteria were identified based on their impact on fire station efficiency and responsiveness, including industrial, commercial, storage, educational, and healthcare centers, as well as filling stations, residential areas, gathering places, road networks, population density, and office buildings. The final desirability map was created by overlaying weighted fuzzy layers in ArcGIS, visually highlighting optimal locations.

FINDINGS: The weighting analysis showed that industrial centers (0.1131) held the highest weight in fire station site selection, while educational centers (0.0735) had the lowest. The final spatial desirability map revealed that 24% of the northern and southwestern areas of District 8 had high suitability for fire station placement. The southwestern area, despite the high operational statistics at Fire Stations 125 and 3 (55%), lacks adequate fire coverage. To address this issue, three potential sites were identified in the high-desirability zone in the southwestern region, with a field survey evaluating neighborhood compatibility, access to networks, and recent urban developments.

CONCLUSION: This study presents a robust framework for optimizing fire service operations in District 8 of Karaj. Through this framework, the region was classified into five categories of desirability for fire station placement. Additionally, the analyses uncovered the unequal distribution of emergency services across the district. The results facilitated the identification of three suitable sites to enhance fire service provision. Given the effectiveness of this methodology, the study strongly recommends that urban planners adopt this innovative framework for emergency site selection, emphasizing the importance of addressing response needs and spatial factors, such as high-density areas and accident-prone centers.

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*Corresponding Author:
Email: *H.karbalaie@ut.ac.ir*
Phone: +989369992359
ORCID: 0009-0003-3148-3316

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INTRODUCTION

Fires can be a great threat to human beings, the built environment, and nature, causing injuries, deaths, economic loss, and pollution (Yao *et al.*, 2019). Fires cause up to 180,000 deaths globally per year; this is more than triple the annual average number of fatalities due to all-natural hazards (Moullier *et al.*, 2020). Over 95% of fire-related deaths and injuries occur in low- and middle-income countries, with incidents in built-up areas rising sharply due to rapid urbanization (Abrassart *et al.*, 2024). As urbanization, climate change, and technological advancements intensify, the risks of fire-related disasters increase, making effective fire prevention and emergency response plans essential (Khalid, 2024). Reasonable construction and strategic placement of fire facilities and stations significantly enhance the government's ability to mitigate or prevent fire-related disasters in urban areas (Lai *et al.*, 2011). However, many cities have an insufficient number of fire stations with heavy workloads (Tao *et al.*, 2022). In rapidly growing cities like Karaj, these challenges are particularly pronounced. District 8 of Karaj, characterized by dense residential developments and the concentration of critical facilities, has experienced rapid urbanization. This unplanned growth, coupled with insufficient fire station coverage, has resulted in significant gaps in emergency response capabilities, leaving the area highly susceptible to fire-related disasters. The basic requirement for improving rescue operations in cities is determining the optimal location for fire department facilities (Macit, 2015). However, the decision-making process for urban land use allocation has always been complex (Arefiev, 2015). Optimal site selection for fire stations demands comprehensive spatial data analysis and a thorough understanding of the spatial relationships that influence emergency response requirements. To address these challenges, Malczewski (2006) suggests that integrating Geographic Information Systems (GIS) with Multiple-Criteria Decision-Making (MCDM) approaches is an effective solution, enabling decision-making based on geographic data and indicator prioritization. Taking advantage of information technology, GIS enables the handling of both spatial and nonspatial data, leading to its specific roles in data management and integration, data query and analysis, and data visualization (Cheng *et al.*, 2007). Moreover, fuzzy set techniques can be utilized in GIS modeling to account for the inherent uncertainty in real-world land-use systems (Grekousis *et al.*, 2012). Despite these strengths, GIS techniques alone exhibit limitations in determining the weights of criteria necessary for site selection. Consequently, these techniques are often paired with MCDM methods to enhance their decision-making capabilities. Among MCDM methods, the Stepwise Weight Assessment Ratio Analysis (SWARA) approach stands out. It is a structured approach that involves breaking down complex decision-making problems into simpler parts and assigning weights to each criterion to determine their relative importance (Akram *et al.*, 2023). This method is an expert-oriented approach to determining the weights of criteria and can be effectively combined with GIS techniques to solve complex location problems. This hybrid approach can provide a more objective and systematic way of making decisions compared to traditional approaches based on intuition or subjective opinions (Ghobadi, 2023). Various studies have examined the optimal fire station site selection methods and criteria. Amlashi (2019) examined the role of fire station placement in enhancing urban safety by employing the Analytic Hierarchy Process (AHP) method with GIS. This study employed AHP to assign weights to criteria, which were subsequently integrated through overlay analysis in ArcGIS to determine ideal sites for fire stations. Nyimbili and Erden (2020) conducted a study to effectively plan the location of emergency facilities for proper service delivery in Istanbul, Turkey. They proposed a fuzzy-AHP approach for the optimal site selection of fire stations. The weights obtained from this approach were validated with the Best-Worst MCDM technique (BWM), which was compatible. In a study, Lai *et al.*, (2011) combined GIS and AHP methods to determine the layout of firefighting facilities and argued that this approach offers greater flexibility and universality, significantly reducing the complexity of site selection. In addition to research focused on fire station site selection, several studies have examined the site selection of various urban services. The application of diverse GIS and MCDM methods in these studies can enhance the process of selecting optimal locations for fire stations. Zandi *et al.*, (2024) focused on creating a hospital site suitability map, considering socio-environmental factors and combining GIS with MCDM

weighting methods. This study employs the Best-Worst Method (BWM) and SWARA to enhance the suitability analysis of hospital sites. Sensitivity analysis revealed that the GIS-based SWARA-Weighted Linear Combination (WLC) model was the most stable and effective approach for determining hospital site suitability in the study area. Da Silva Romero *et al.*, (2023) focused on developing a multi-criteria model that integrates GIS and fuzzy logic to identify suitable areas for the implementation of biorefineries. They compared the created model with the middle center and Boolean logic models and claimed that the GIS-FUZZY model provides better results than other models. In a study to select a landfill site, Ghobadi (2023) proposed a GIS-based SWARA method in the east of Lorestan province, Iran. He stated that the proposed method provides decision-makers with a systematic approach to evaluating and ranking potential sites based on their suitability. Wang *et al.*, (2022) used a location decision model based on GIS and improved TOPSIS to locate integrated energy stations in Tianjin, China. This study develops an evaluation index system covering nature, economy, and society, using the AHP method to calculate index weights. The GIS overlay function integrates related layers, and the improved TOPSIS model ranks the alternatives to determine the optimal choice. The literature shows that while various MCDM methods and GIS techniques are commonly used for facility and infrastructure site selection, advanced methodologies for fire station site selection remain underutilized. This is despite the inherently complex nature of decision-making required for urban emergency services. Among these methods, the SWARA method stands out due to its ability to integrate complex spatial relationships and expert judgment. When combined with fuzzy logic techniques in GIS, SWARA provides urban planners with a powerful tool for optimizing fire station placement, potentially offering advantages over traditional approaches. District 8 of Karaj is rapidly expanding, with new constructions, industrial centers, and institutions such as hospitals and universities attracting a growing population. To meet the increasing demand, expanding emergency services, especially by adding fire stations, is crucial. However, few studies have focused on selecting optimal sites for fire stations in this area, and existing research has several limitations. First, previous studies often relied on a narrow set of criteria, failing to capture the complexities of the urban system that are essential for effective fire station site selection. They also overlooked important spatial characteristics that are critical for efficient emergency response and fire station performance. Second, these studies did not incorporate advanced decision-making methods like the SWARA method, which enables better alignment with decision-making needs. This study addresses the critical need for improved fire station infrastructure in District 8 of Karaj by proposing a novel approach for site selection that integrates comprehensive criteria, the SWARA method, and fuzzy logic within ArcGIS techniques to optimize fire station placement in 2025.

MATERIALS AND METHODS

Description of the study area

Karaj, with a population of 1,592,000, is the fourth most populous city in Iran and a key destination for immigrants. District 8, located in the northeastern part of Karaj, has a population of 135,000. This area is characterized by diverse land uses, increasing construction activity, and heavy traffic during peak hours. The combination of these land uses has transformed the city into a multi-functional urban space, complicating the spatial relationships between them. Moreover, the presence of population-attracting centers, such as universities and healthcare facilities, underscores the need for fire infrastructure that can meet the region's growing demands. Fig. 1 illustrates the location of the study area and current fire stations. District 8 currently has three fire stations. Stations 3 and 129 are grand stations with advanced capabilities, while Station 125 is a small station with more limited resources. Despite the heavy traffic and notable accident and fire statistics in the southern part of District 8, Station 125's limited capacity often necessitates support from other stations during major incidents. Station 3, positioned on the boundary between Districts 8 and 7, is occasionally deployed to handle fires and accidents in District 7. In contrast, Station 129 benefits from a strategically advantageous location, with its central position, modern facilities, proximity to densely populated and sensitive areas, and easy access to the main road network significantly enhancing its effectiveness. A statistical analysis of fire station operations from 2020 to 2023 revealed that District 8 recorded a total of

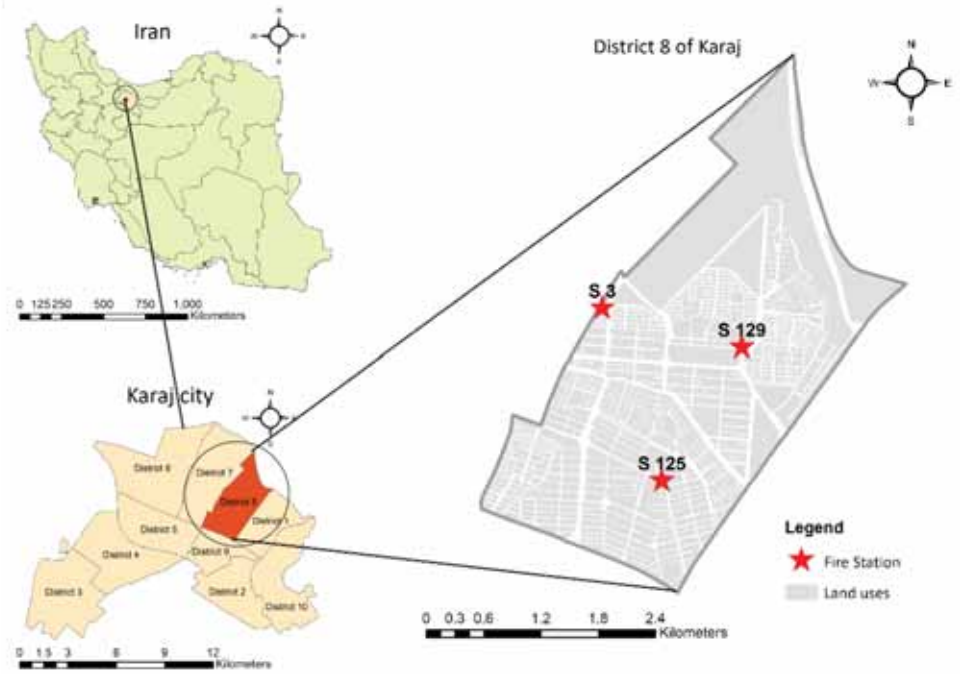

Fig. 1: Geographic location of the study area in District 8 of Karaj

2,412 missions related to incidents and fires. Among these, Station 129 responded to 706 missions, Station 125 to 909 missions, and Station 3 to 345 missions. Furthermore, fire stations located outside District 8 contributed to 371 missions within the district during this period. Fig. 2 provides a visual representation of the percentage of station involvement in missions from 2020 to 2023.

Development of the research process

The process of selecting optimal locations for fire stations using the SWARA fuzzy-GIS method was carried out in eight systematic steps, as illustrated in Fig. 3. Before initiating the methodological steps, a comprehensive assessment of the study area was conducted to define the research objectives and approach. This preliminary stage involved consultations with local firefighting experts, analysis of mission statistics, and an evaluation of existing resources and the operational capacities of current fire stations. Subsequently, in the first step, eleven criteria for fire station site selection were identified. These criteria were established through a review of relevant literature, adherence to regional fire station establishment standards, and expert opinions from fire services. In the second and third steps, the participating experts assigned weights to each criterion, with the final weights calculated using the SWARA method. The experts involved in this process were all professionals from the fire department, including both fire service specialists and active firefighters. The key criteria for fire station site selection are summarized in Table 1. The fourth step involved gathering, digitizing, updating, and modifying criteria-related documents and spatial layers in ArcGIS software. To ensure the accuracy of the spatial data, digitized layers were corrected and updated through the review of recent documents and satellite imagery. In the fifth step, each layer was transformed into a fuzzy raster by determining its fuzzy membership type based on the specific definition of each criterion. In the sixth step, the raster layers were weighted according to the SWARA findings. The seventh step involved generating an optimal location map through a fuzzy overlay of the 11 weighted and fuzzified layers. Finally, in the eighth step, a field survey was conducted to validate the map results and ensure the accuracy of the optimal locations. This survey assessed factors such as neighborhood compatibility and significant urban

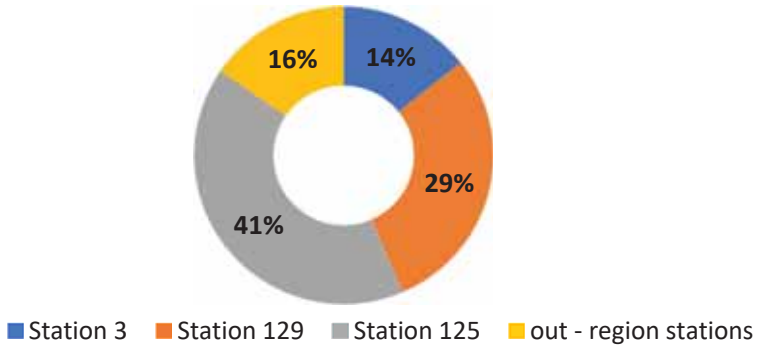

Fig. 2: The percentage of fire and accident missions of stations in Karaj District 8 from 2020 to 2023

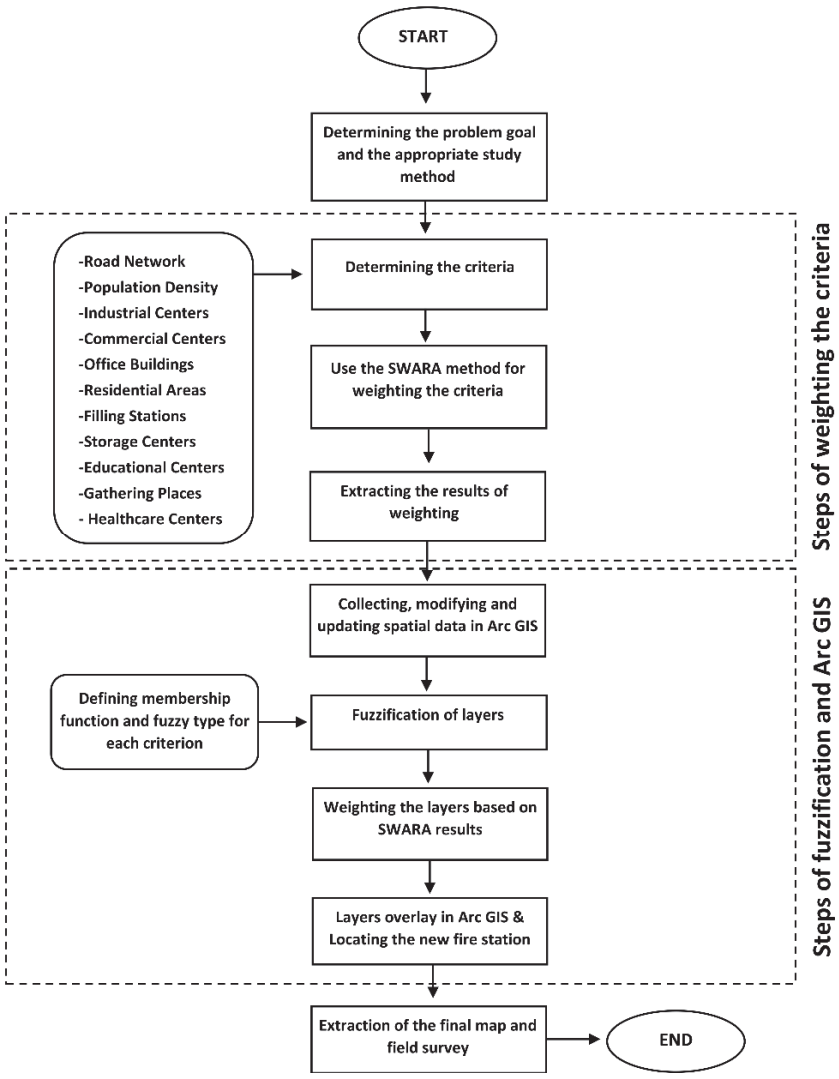

Fig. 3: Diagram of the research process

Table 1: Description of the suitability criteria

	Criteria	Suitability	Reference
C1	**Road Network**	Proximity to the main road and streets with a width of more than 15 meters.	Habibi *et al.*, (2008) Amlashi (2019) Erden and Coskun (2010) Ziari and Yazdan.P (2011) ISIRI (2001)
C2	**Population Density**	A denser population is prone to more accidents. One fire station for every 50,000 people.	Habibi *et al.* (2008) Amlashi (2019) Lai *et al.* (2011) Erden and Coskun (2010) Johnson (1999)
C3	**Industrial Centers**	Proximity to industrial centers due to flammable and chemical substances.	Habibi *et al.*, (2008) ISIRI (2001)
C4	**Commercial Centers**	Proximity to commercial centers that contain flammable materials such as plastic, cloth, and paper, and the presence of large crowds in places such as stores and markets.	Johnson (1999) Amlashi (2019) ISIRI (2001)
C5	**Office Buildings**	Proximity to office centers due to the gathering and movement of people and the use of flammable materials such as paper and electronic devices.	Johnson (1999) ISIRI (2001) Amlashi (2019)
C6	**Residential Area**	Proximity to neighborhoods with high housing density due to density in population, fuel, and food, which are flammable and prone to life and financial damage.	Johnson (1999) Amlashi (2019)
C7	**Filling Stations**	Proximity to gasoline and gas stations, which have a large volume of flammable materials and are prone to ignition and explosion, and due to providing services to the fire trucks.	Habibi *et al.* (2008) Amlashi (2019) Nisanci *et al.* (2012)
C8	**Storage Centers**	Proximity to storage centers due to the storage of a large amount of various flammable items.	Amlashi (2019) ISIRI (2001) Nisanci *et al.* (2012)
C9	**Educational Centers**	Proximity to these institutions is due to gathering in these places within a 500-meter limit. because these institutions have traffic at certain times of the day.	Johnson (1999) ISIRI (2001) Şen *et al.* (2011)
C10	**Gathering Places**	Proximity to gathering places within a 500-meter. In order not to disrupt the service of fire stations due to the traffic of gathering centers, restrictions should be placed on proximity to these centers.	Amlashi (2019) ISIRI (2001)
C11	**Healthcare Centers**	Proximity to medical centers with a 500-meter limit. Due to the sensitivity of healthcare centers to noise pollution and the presence of traffic around these centers.	Johnson (1999) Habibi *et al.* (2008) Amlashi (2019) ISIRI (2001) Nsaif and Al-Obaidi (2022)

changes to ensure the practical feasibility of the proposed fire station sites.

The criteria

The criteria for fire station site selection have been established based on a review of previous studies, expert opinions, and regional standards for fire station locations. The criteria are listed in Table 1. Every criterion had an impact on the effectiveness and responsiveness of fire stations as well as the necessity for fire services. A comprehensive understanding of each criterion's definition is essential as it encompasses key information, including its impact on the distance and proximity of fire stations, its compatibility with neighboring stations, and the evaluation of relevant limits. Fire stations are generally compatible with densely populated areas, industrial and commercial centers, and filling stations; however, they face compatibility challenges when located near healthcare and educational facilities due to traffic and congestion near these centers. It is important to consider regional standards when selecting and determining criteria in fire station site selection studies, as this ensures the maximization of the cost-benefit ratio for the community in the selection of suitable sites for specific land uses (Hailemariam, 2021). Therefore, in this study, the selection and determination of acceptable values for certain criteria have been based on regional standards.

Fuzzy-GIS Multi-Criteria method

The SWARA method provides an opportunity for policymakers to choose the best decision based on dissimilar situations and import criteria based on their wants and objectives (Majeed & Breesam, 2021). It is a completely judgmental method, and

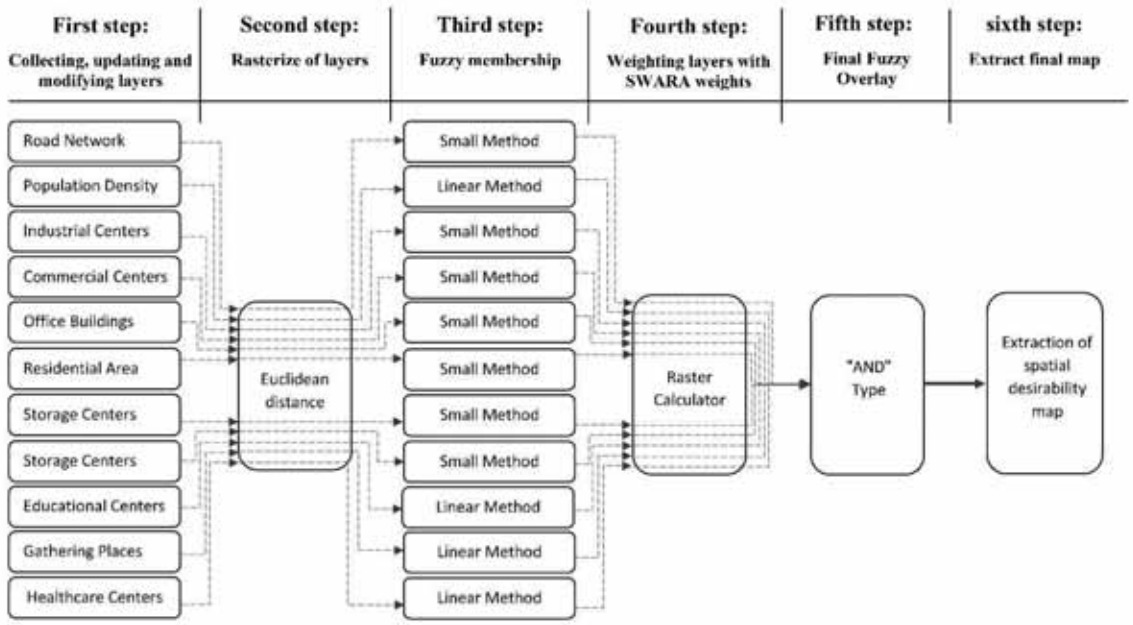

Fig. 4: Steps of fuzzification and Arc GIS

experts (respondents) play an important role in determining the weight of criteria; moreover, the number of pairwise comparisons has been reduced, and attention has been paid to the uncertainty in the evaluation (Dehshiri and Firoozabadi, 2023). These attributes make the SWARA method a powerful tool for spatial studies, enabling it to produce results that closely align with expert opinions and real-world conditions. In this study, the SWARA method has been employed for weighting the criteria for fire station site selection to ensure the final weights are highly consistent with expert opinions while minimizing ambiguity. The main steps for weighting based on the SWARA method are as follows:

1. Sorting the criteria:

Once the final criteria are identified, they are ranked based on their level of importance.

2. Comparative significance (Sj):

In this step, the relative importance of each criterion is assessed in comparison to the previous, more important criterion. This value is represented by Sj.

3. Calculating the coefficient (Kj):

The coefficient Kj reflects the relative importance of each criterion and is calculated using the following formula:

$$kj = Sj + 1$$

4. Calculating the initial weight of each criterion (Qj):

The initial weight of each criterion is determined using the formula:

$$Qj = Qj - 1 / Kj$$

5. Calculation of the final normal weight (Wj):

The final weight of the criteria, which represents the normalized weight, is computed using the following formula:

$$Wj = Qj / \sum \mathrm{Qj}$$

In addition to the appropriate selection and weighting of criteria, it is imperative to employ analytical tools and modeling techniques within ArcGIS software that more accurately represent the complex spatial relationships between criteria in the real world. In GIS, analytical functions and traditional cartographic modeling methods based on Boolean logic implicitly assume that objects

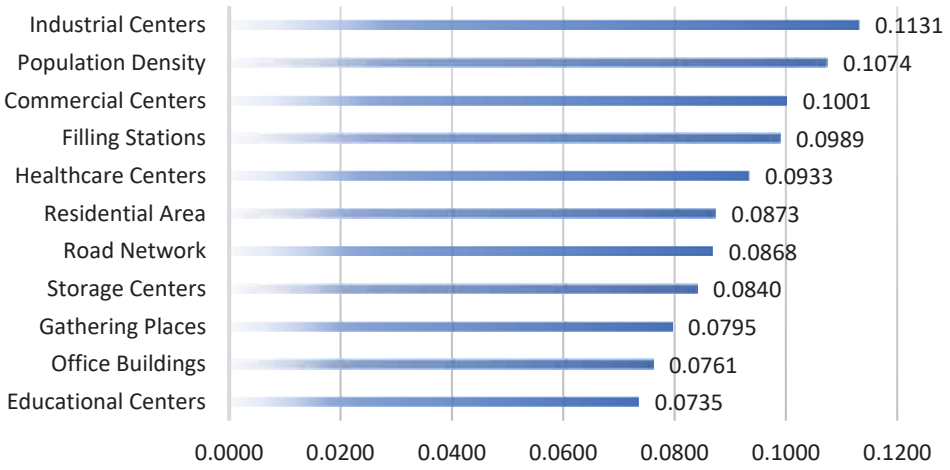

Fig. 5: The weight rating of criteria

in a spatial database and their characteristics are uniquely defined. However, the inherent constraints of classical set theory do not allow for partial set membership or imprecise information in GIS. The inadequacy of Boolean logic in representing and manipulating spatial data poses a significant obstacle to realistic GIS modeling (Sui, 1992). To better represent environmental issues in modeling, fuzzy logic provides a more nuanced approach than Boolean logic. By transforming data into a fuzzy raster set with membership grades, the degree to which each cell belongs to a specific feature can be assessed. Fuzzy operators and functions in ArcGIS software enable both *(1) scaling criteria according to each criterion's range*

(2) overlaying criteria as raster layers.

Given the aforementioned advantages, this study integrates fuzzy-GIS techniques with the SWARA method to effectively model spatial criteria and optimize the placement of fire stations in District 8. Fig. 5 illustrates the key steps in ArcGIS for creating a spatial desirability map, starting with data collection and ending with the production of the final map.

RESULTS AND DISCUSSION

The final weight of criteria in the SWARA method ranges from 0 to 1. Table 2 and Fig. 5 show the weight of each criterion according to experts' opinions and its final weight. Criteria such as industrial centers (weight: 0.1131) were assigned higher weights due to their critical role in fire station location planning, as these areas are associated with higher fire risks due to flammable materials, hazardous processes, and dense infrastructure. In contrast, criteria such as educational centers (weight: 0.0735) received lower weights, as schools generally pose lower fire risks and have fewer incidents compared to other centers evaluated in the study. Karaj District 8 is an urban area characterized by diverse land uses. The high weights assigned to industrial centers, commercial centers (weight: 0.1001), densely populated areas (weight: 0.1074), and filling stations (weight: 0.0989) in the weighting table reflect the concentration of factories, workshops, malls, and flammable materials in the region, all of which contribute to an increased risk of accidents and fires. Many fire station location studies overlook the diversity of land uses, neglecting not only the spatial relationships between these centers but also their service requirements and their impact on the response efficiency of fire stations. By integrating local characteristics into the analysis and weighting process, this approach provides a practical tool for optimizing fire station locations in Karaj District 8.

Raster layers of criteria

The rasterized maps of the 11 criteria, shown in Fig. 6, provide valuable insights into the spatial distribution of key factors influencing fire station

Table 2: Total weight of site selection criteria of fire stations based on SWARA method

	Criteria	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7	Weighted average
C1	Road Network	0.0595	0.1054	0.0565	0.0871	0.1023	0.1055	0.0913	0.0868
C2	Population Density	0.1095	0.1102	0.1083	0.1065	0.1023	0.1234	0.0913	0.1074
C3	Industrial Centers	0.1255	0.0890	0.1114	0.0992	0.1179	0.1234	0.1252	0.1131
C4	Commercial Centers	0.1095	0.0867	0.1035	0.0871	0.1108	0.1156	0.0874	0.1001
C5	Office Buildings	0.0695	0.0795	0.0614	0.0819	0.1108	0.0639	0.0657	0.0761
C6	Residential Area	0.0915	0.1035	0.0989	0.0871	0.0759	0.0739	0.0804	0.0873
C7	Filling Stations	0.1195	0.0906	0.0945	0.0949	0.0671	0.0947	0.1309	0.0989
C8	Storage Centers	0.1045	0.0795	0.0928	0.0856	0.0586	0.0739	0.0930	0.0840
C9	Educational Centers	0.0725	0.0676	0.0697	0.0841	0.0759	0.0844	0.0606	0.0735
C10	Gathering Places	0.0645	0.0676	0.1166	0.1001	0.0847	0.0464	0.0770	0.0795
C11	Healthcare Centers	0.0745	0.1205	0.0864	0.0864	0.0938	0.0947	0.0971	0.0933

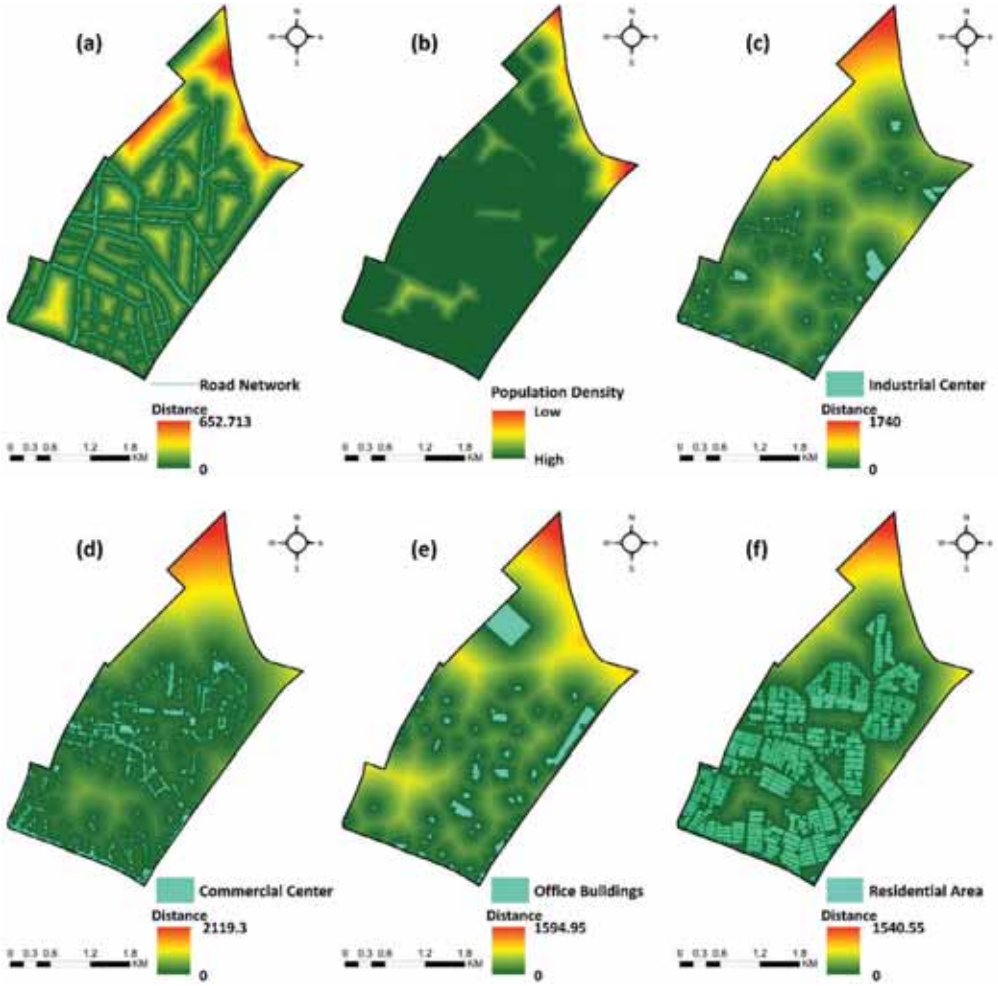

Fig. 6: Rasterized maps of criteria

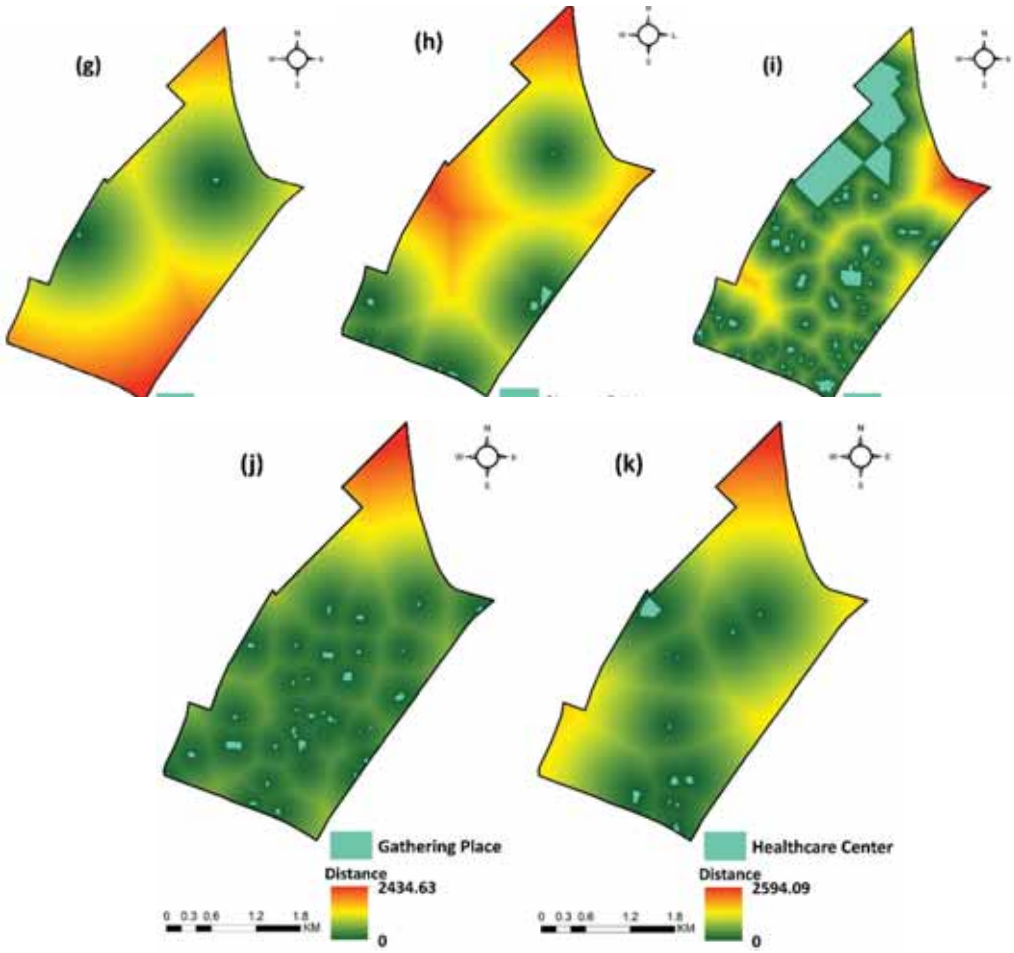

Fig. 6: Rasterized maps of criteria

placement in Karaj District 8. As depicted in Fig. 6(a), the northern areas, characterized by barren land and ongoing construction, have the least developed road network. Due to the lack of essential infrastructure and a comprehensive road system, this region is considered a lower priority for fire station placement. Fig. 6(b) shows that the northern and northwestern areas of the district have the lowest population density, indicating that fire stations may not be as critical in these regions. The spatial distribution of industrial centers (Fig. 6(c)) and commercial centers (Fig. 6(d)) is spread throughout District 8. Given the high weights assigned to these criteria in the weighting process, their dispersed distribution (except the northern area) underscores the importance of strategically positioning fire stations to ensure broad coverage and accessibility. Office buildings (Fig. 6(e)) and educational centers (Fig. 6(i)) were among the least weighted criteria in the fire station placement weighting process. Both are scattered across District 8 and exhibit lower fire risks compared to other sensitive areas. However, they must still be considered in fire station location planning due to the presence of flammable materials, vulnerable individuals, and the concentration of people within these facilities. A prominent feature of District 8 is the rapid development of residential areas, particularly in the center and southern parts of the district (Fig. 6(f)), driven by high migration rates. The presence of flammable materials in homes further emphasizes the importance of placing fire stations in proximity to these areas to reduce response times and mitigate fire risks. Filling stations, highlighted in Fig. 6(g), are in the northeastern and western parts of the district,

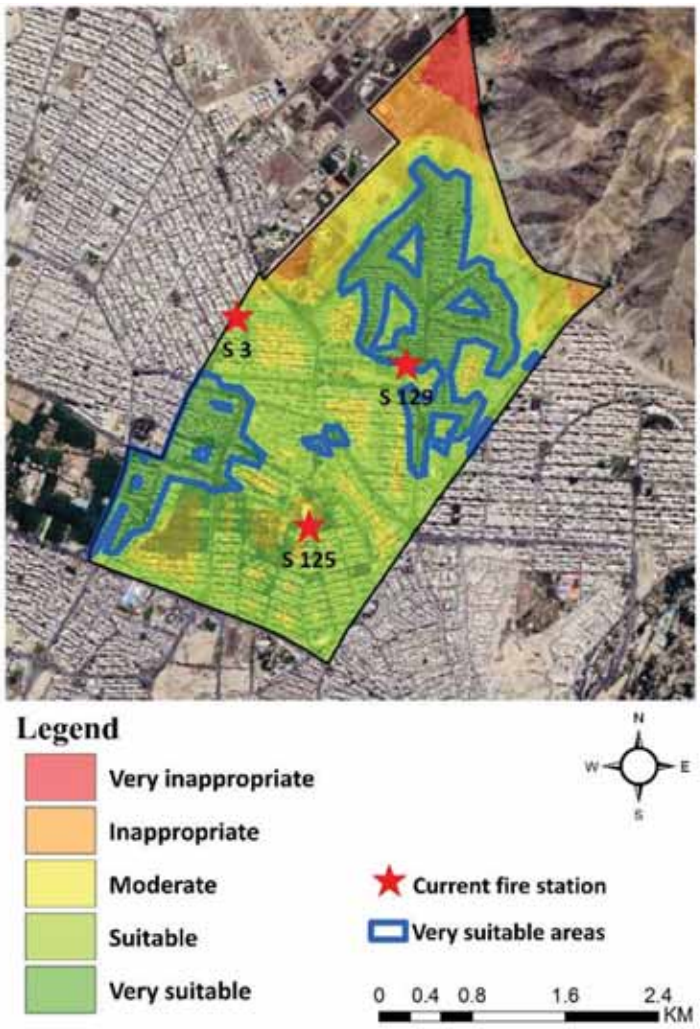

Fig. 7: Fire station suitability areas map

and Fig. 6(h) shows a concentration of storage centers in the southern and western regions. These areas, with their higher fire risks due to the constant accumulation of fuel, flammable materials, and the transportation of these substances, necessitate the presence of fire stations nearby to ensure rapid responses and minimize potential damage. District 8 of Karaj includes various gathering places, such as mosques and halls (Fig. 6(j)), which require fire stations due to the sensitivity of large crowds and flammable materials. To ensure optimal accessibility and response times, these centers should be situated at least 500 meters from fire stations, considering the traffic and congestion they generate at specific times.

District 8 of Karaj hosts several major healthcare centers, as shown in Fig. 6(k), particularly in its central and southern areas. Due to factors such as population density, vulnerability of individuals, and the presence of flammable materials, these hospitals require nearby fire stations. To balance accessibility and operational efficiency, fire stations should ideally be located within a 500-meter radius of hospitals, considering visitor traffic and noise sensitivity. Given the nature of spatial relationships, the criteria are interdependent and mutually influence each other in determining the optimal locations for fire stations and the final suitability map. For example, in District 8 of Karaj, areas near densely populated, industrial,

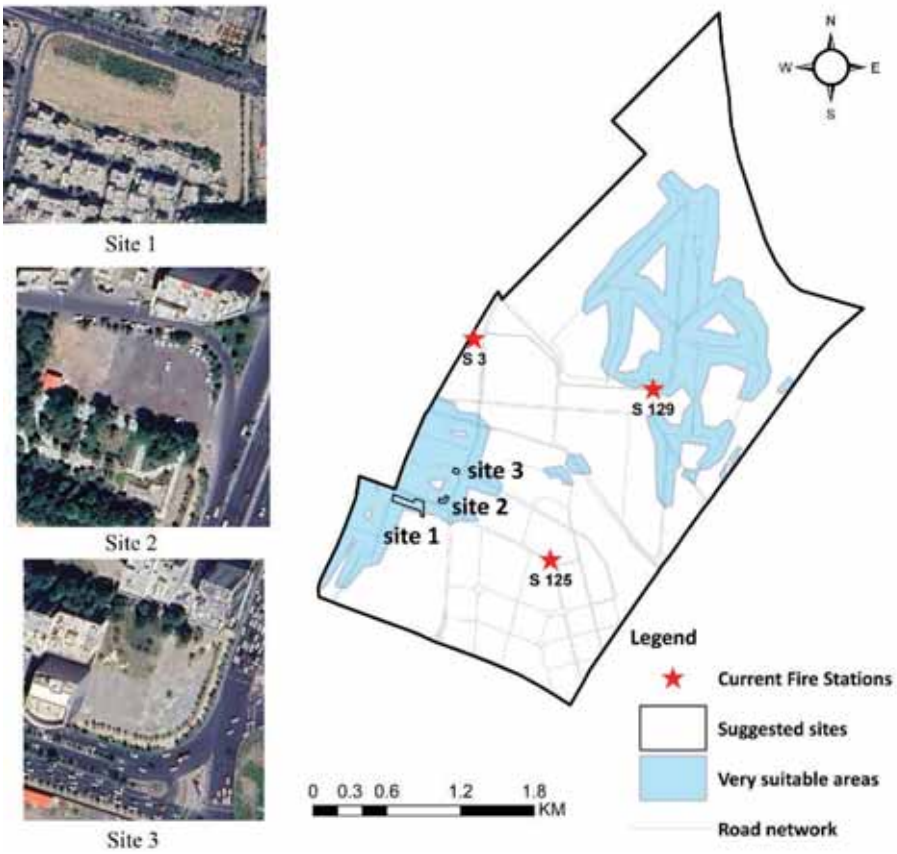

Fig. 8: Location of suggested sites

and commercial centers are prioritized by experts to enhance safety and reduce response times, thereby having a greater impact on the final suitability map. Additionally, centers with specific distance constraints to fire stations, such as hospitals and meeting centers, also play a significant role in the final analysis and station placement. By accounting for these interdependencies, a comprehensive framework for fire station placement can be developed for Karaj District 8, ensuring optimal coverage, accessibility, and safety across the region.

Suitable areas map

The final desirability map, shown in Fig. 7, was generated by overlaying the fuzzy-weighted layers of all criteria. This map classifies the study area into five suitability categories: very suitable, suitable, moderately suitable, inappropriate, and very inappropriate. The red regions represent areas least suitable for fire station placement, while the dark green regions indicate the most optimal locations. Highly suitable areas constitute 24.87% of the total area, followed by suitable areas at 48.38%, moderately suitable areas at 19.3%, inappropriate areas at 4.98%, and very inappropriate areas at 2.46%. Notably, two prominent zones classified as highly suitable are in the northern and southwestern parts of the district. These zones are strategically situated in proximity to critical infrastructure, including arterial roads, industrial hubs, commercial centers, and densely populated residential neighborhoods. An analysis of fire station mission statistics, along with a comparative review of the suitability map and the current distribution of fire stations in District 8, reveals a substantial gap between the region's emergency service needs and its existing infrastructure, particularly in the southwestern areas. The suitability map underscores the uneven distribution of emergency services and assists in identifying optimal locations for future fire stations. Leveraging these insights for the development of

fire station infrastructure will enhance emergency response efficiency and mitigate fire risks in high-priority areas.

Determination of susceptible areas

This study identifies three strategic sites for the establishment of new fire stations in District 8 of Karaj, in the southwest region (Fig. 8). These areas were selected based on a comprehensive analysis of several criteria, including accident and fire statistics, population density, and critical facilities. The southwest zone stands out due to its proximity to densely populated residential areas, industrial complexes, and commercial centers, which create an elevated demand for emergency services. The selected sites in the southwest align with the suitability map generated using the SWARA GIS-Fuzzy model, which considers urban development patterns, accessibility to main roads, and proximity to high-risk areas. These sites were confirmed through field visits and spatial evaluations, ensuring they met critical planning requirements and addressed existing service gaps. By enhancing response times and improving coverage in high-risk zones, these proposed sites aim to bolster the district's firefighting infrastructure and overall resilience to fire-related emergencies.

Limitations and future research

To address the limitations of this study, which focused on the optimal site selection of fire stations to improve emergency response, it is important to acknowledge that the lack of open access to reliable databases from relevant governmental organizations posed significant challenges. Specifically, sensitive data, such as population density, could not be obtained with the level of accuracy required. Given the dynamic nature of population changes, up-to-date data was critical for precise decision-making. Unfortunately, the study had to rely on available, less accurate data due to this limitation. To mitigate this issue, the researchers conducted additional validation procedures using calculations from other data sources. While this study utilized a Fuzzy-GIS SWARA model, future studies could refine this approach by integrating real-time traffic patterns, temporal variations in population density, and other dynamic factors. Additionally, for regions prone to natural disasters, it would be beneficial to include specific risks, such as proximity to earthquake fault lines, in the site selection process. These targeted improvements could enhance the precision and applicability of emergency response planning, ensuring that fire stations are optimally located to handle both everyday incidents and extraordinary events.

CONCLUSION

This study investigated the optimal placement of fire stations in Karaj District 8 to improve emergency response capabilities. By combining SWARA and fuzzy techniques within the ArcGIS framework, a comprehensive model for fire station site selection was developed. The research identified 11 key criteria influencing the need for fire station services, including industrial centers and densely populated areas, which were found to be the most critical factors. Educational centers and office buildings were deemed less impactful. The suitability map showed that 24.87% of District 8 was highly suitable for fire station placement, with the northern and southwestern regions being the most optimal. To address the pressing needs in the southern to western areas, three potential sites for a new fire station were proposed in the highly suitable southwestern region (Fig. 8). The hybrid methodology used in this study effectively addresses the complexities of fire station site selection in District 8 of Karaj, providing urban planners with a reliable tool to align firefighting infrastructure with the increasing service demands and challenges posed by population growth and urban development in the region. The final analysis of the current distribution of fire infrastructure and service needs provides crucial guidance for addressing the unequal allocation of emergency services throughout the district. To address the disparities in firefighting coverage, resource allocation should prioritize establishing auxiliary fire stations in high-demand areas, such as the southwestern region, to enhance emergency response capabilities. Additionally, engaging local communities and key stakeholders, including owners of high-risk facilities and industries as well as officials from organizations influencing fire station operations, during the planning stages can help ensure that new fire facilities are aligned with neighborhood needs and integrated into broader urban development strategies. The SWARA Fuzzy-GIS approach offers superior capabilities compared to

existing methods, particularly in reducing uncertainty and improving decision-making accuracy for fire station site selection. Its ability to integrate spatial criteria and account for their complex interrelations makes it highly adaptable to diverse emergency site selection contexts. This model's flexibility underscores its potential for broader application across various regions and urban planning scenarios. This study recommends that urban planners, crisis managers, and other stakeholders adopt efficient methods, including the model presented here, for the planning, implementation, and evaluation of fire station site selection. Future research should expand this model's application to other regions, integrating dynamic factors like real-time traffic patterns, population changes, and the impact of fire station rankings.

AUTHOR CONTRIBUTIONS

H. Karbalaie contributed to the literature review, collected relevant documents and spatial data related to the selection criteria, created GIS maps, analyzed the spatial data, and was responsible for writing and editing the manuscript. F. Izadbin contributed to the literature review, applied the SWARA weighting method, gathered operational statistics, and consulted with experts from the Karaj Fire Department.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS

AHP	Analytic Hierarchy Process
BWM	Best-Worst MCDM technique
GIS	Geographic Information Systems
ISIRI	Iran National Standards Organization
Kj	Coefficient value
MCDM	Multiple-Criteria Decision-Making
Qj	Initial weight
SWARA	Stepwise Weight Assessment Ratio Analysis
SPP	Solar Power Plant
Sj	Comparative significance value
Wj	Final normal weight

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ORIGINAL RESEARCH PAPER

Social capital and its impact on poverty reduction: Rural-agriculture and urban-multisector underprivileged communities

A. Faisal[1,*], M. Saleh S. Ali[1], R. Rahmadanih[2], H. Ch. Lakare[2]

[1] *Development Studies Program, Graduate School of Hasanuddin University, Makassar, Indonesia*

[2] *Department of Agriculture Socio Economics, Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia*

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ABSTRACT

BACKGROUND AND OBJECTIVES: Poverty remains a critical issue in many regions of Indonesia, requiring comprehensive solutions. Social capital, a critical non-economic factor, emerged as an essential tool in empowering communities to reduce poverty. This study aims to explore the social capital among underprivileged households in Enrekang Regency and offers practical models to enhance poverty alleviation.

METHODS: Data were collected through a structured questionnaire and in-depth interviews with 140 heads of underprivileged households in Enrekang Regency, Indonesia, covering both rural-agricultural and urban-multi-sector areas. The data were analyzed using a nonparametric analysis method, while the significance of social capital was assessed using the Mann-Whitney test. The social capital variables investigated in this research included trust, groups and networks, norms, information and communication, cohesiveness, and reciprocity.

FINDINGS: The findings revealed that social capital tended to be stronger in rural-agricultural areas than urban-multisector regions. Factors such as homogeneity, kinship, local institutions, and traditional values were foundational elements of social capital. Social capital is primarily utilized to fulfill basic survival needs rather than to pursue profit maximization. Practices such as mutual assistance during farming activities (e.g., fertilization, planting, pest control), the sharing of harvests for collective consumption, and local kiosks providing loan mechanisms demonstrate the vital role of social capital in sustaining daily life. Predominantly, the social capital identified in these communities is bonding social capital (internal solidarity), with limited progression towards bridging social capital, which could better connect various resources within and beyond the community.

CONCLUSION: In conclusion, the strategy for leveraging social capital in poverty alleviation in Enrekang was developed through two models: (a) the rural-agriculture model and (b) the urban-multisector model. Both models emphasized strengthening ties among families, neighborhoods, and community groups. These relationships were optimized to shift from bonding to bridging social capital, enhancing the overall effectiveness of poverty alleviation initiatives.

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*Corresponding Author:
Email: *achmad.faisal81@yahoo.com*
Phone: +62 81343588333
ORCID: 0009-0007-1839-6700

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INTRODUCTION

Poverty, as a humanitarian issue, has attracted significant global attention, compelling countries worldwide to seek sustainable solutions (Todaro and Smith, 2015). It fundamentally reflects a state of deprivation and vulnerability, stemming from an individual's inability to meet basic needs and the absence of sufficient social protection from the state or society. This condition underscores the need for global commitment and prioritization of poverty alleviation as a central development goal, prominently featured in the Sustainable Development Goals (Sachs, 2012; United Nations, 2019). Poverty reduction has thus become a key indicator for evaluating development success across various nations. Indonesia's national poverty rate in March 2024 reached 9.03 percent or 25.22 million people, with 11.64 million in urban areas and 13.58 million in rural areas (Badan Pusat Statistik, 2024). The poverty rate also remains a pressing issue in Enrekang Regency, with 11.25 percent, or 24.060 people, below the poverty line (Badan Pusat Statistik Provinsi Sulawesi Selatan, 2024). Over the past ten years, Enrekang has consistently ranked among the five poorest regencies out of 24 in South Sulawesi. As of 2024, it holds the fourth-highest poverty rate in the province. Despite these challenges, poverty alleviation policies often remain constrained by a limited analytical framework, treating poverty merely as a deficit in income or economic resources. This perspective tends to confine poverty reduction efforts to the quantification of income and expenditure. The dominance of economic considerations is evident in poverty measurements that rely on 'income' as the main criterion for defining the 'poverty line'. While economic growth is essential for improving the living conditions of the underprivileged community, it is not necessarily beneficial, as it often disproportionately favors the more privileged sectors of society (Sen, 1985). Chambers (1983) criticized these policies because they were just

(1) a top-down approach,
(2) exclusion of local knowledge,
(3) lack of community involvement,
(4) inadequate comprehensive strategies, and
(5) an excessive focus on economic aspects.

The economic approach tends to overlook the important role of social capital, which is an integral part of development but is frequently ignored and regarded as a 'missing link'. As a result, it fails to capture the cultural choices, social-political factors, and other decisions made by underprivileged communities. The underprivileged community is often seen as passive victims, rather than as active participants capable of identifying their conditions and striving for improvement. In contrast, social structures reveal the deep and consistent relationships among individuals in addressing poverty. Social inclusion, which removes social barriers, is just as critical as financial inclusion in poverty reduction strategies, aimed at reducing vulnerability, risk, and deprivation (Burton, 2013; Elkins, 2014). This research seeks to address this gap. This study aims to contribute by emphasizing the social capital in poverty research, focusing on identifying what the underprivileged communities have, rather than what they lack, with the belief that underprivileged households possess the potential to leverage available resources within their communities. Previous studies have consistently highlighted the role of social capital as a key enabler of effective cooperation in delivering services that benefit entire communities (Christiaan, 1998; Krishn and Uphoff, 2002; Narayan and Pritchett, 1999). By fostering trust, norms, and networks, social capital can act as a bridge, enabling communities to access productive resources, such as bank credit, through their social connections (Grootaert, 2001; Van Bastelaer, 2000). This is particularly relevant given the complex and multidimensional nature of poverty, which must be addressed through community-level interventions. Social capital reflects the patterns of social interaction within a society, especially in terms of access to networks and participation in collective groups (Woolcock and Narayan, 2000). It can contribute to poverty reduction when these networks facilitate the exchange of resources, such as information, employment opportunities, financial assistance, or knowledge, between poorer and more affluent groups (Grootaert, 2001). The ongoing process of social interaction, in turn, generates social capital that promotes collective action and mutual benefit (Krishna and Uphoff, 2002). Communities with diverse and inclusive social networks are therefore better positioned to build resilience and combat poverty (Woolcock and Narayan, 2000). Moreover, social capital emerges as a critical non-economic factor that can help bridge this gap and enhance the capacity of marginalized groups to improve their livelihoods. Putman (1993) popularized the concept of social capital as a feature of social organization, including networks,

norms, and trust, that facilitates coordination and cooperation for mutual benefit. He emphasized that social capital enhances the returns on investment in both physical and human capital. In his later works (Putman, 1995), Putman further defined social capital as a collection of individual relationships embedded in networks of social ties, governed by shared norms, and influencing community productivity through civic engagement. These social networks form a dynamic infrastructure that enables interaction, fosters trust and cooperation, and amplifies the benefits of collective participation. The structure and composition of these networks, shaped by elements such as kinship systems, social institutions, and informal ties, are believed to influence poverty outcomes by determining access to economic resources, problem-solving strategies, profit-generating capacity, and decision-making power. Accordingly, this study aims to explore the social capital among underprivileged households and offers practical models to enhance poverty alleviation. The research survey was conducted in Enrekang Regency, Indonesia, in 2024.

MATERIALS AND METHODS

Study area

This research was conducted in Enrekang Regency, South Sulawesi Province, Indonesia (Fig. 1). This region was chosen because it is one of the most impoverished regions in Indonesia. The study began with the purposive selection of three sub-districts, followed by the purposive selection of villages within each sub-district. Villages were chosen to represent specific stages of village development as defined by (Junaidi *et al*., 2012; Rustiadi *et al*., 2009), which include the marketable surplus stage, early primary industry stage, advanced primary industry stage, and secondary industry stage. Based on the observed economic diversity within the research population, the areas have been divided into two categories according to their stage of economic development. The marketable surplus and early primary industry stages are grouped as rural-agriculture areas, which are characterized by less developed economic activities and a continued reliance on agriculture. On the other hand, the advanced primary industry and secondary industry stages are classified as urban-multisector areas, which feature not only the development of economic activities beyond agriculture but also the growth of trade and both downstream agricultural and non-agricultural industries.

Population and sample

The population in this study consists of the lowest decile of underprivileged households, particularly

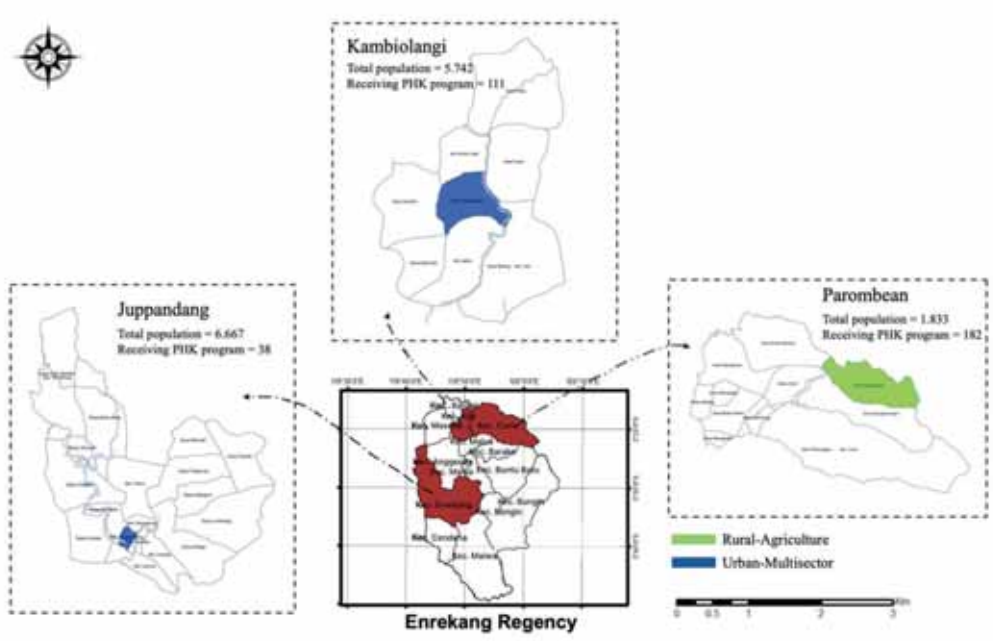

Fig.1: Geographic location of the study area

Table 1: Population and sample

Category Area	Sub-district	Study Area (Village)	Population	Sample	Percentage
Urban-Multisector	Enrekang	Juppandang	38	38	100%
	Alla	Kambiolangi	111	39	35%
Rural-Agriculture	Curio	Parombean	182	63	35%
Total			331	140	

Source: Processed data from the Enrekang Regency Social Service, 2023

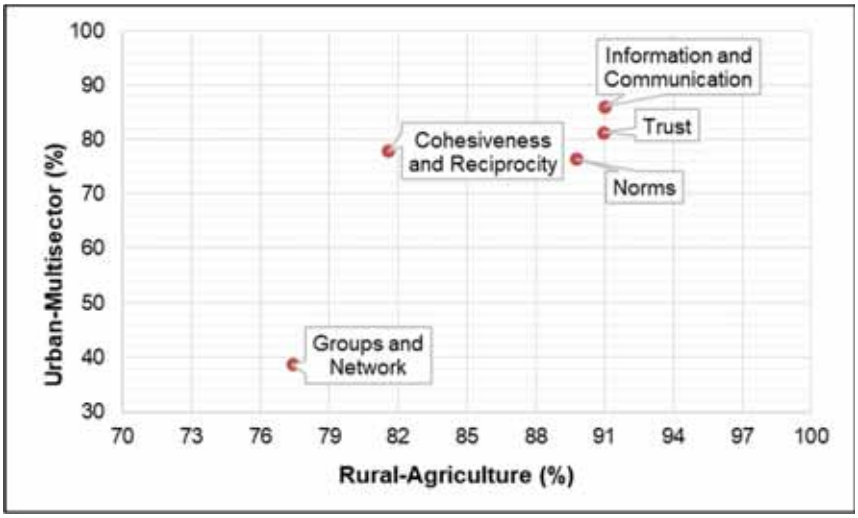

Fig. 2: The mapping of underprivileged households' social capital in Enrekang Regency

those who are beneficiaries of the Family Hope Program (PKH). Population data was collected by referring to the PKH beneficiary household records of the Enrekang Regency Social Service in 2023. Furthermore, the sample was taken from the population, which was selected using a stratified random sampling method. (Rangkuti, 2019) stipulates that if the population exceeds 1,000, a sample size of approximately 10% is recommended; if the population is around 100, at least 30% should be sampled; and if the population is 30, then a 100% sample is required. The sample for each study area is determined in Table 1.

Data collection and analysis

The data collection used in this study consisted of questionnaires and interviews. The researchers employed a closed-ended questionnaire with predefined answer choices, allowing respondents to select from the available options. Each response was assigned a value using a Likert scale, with ratings ranging from 1 (strongly disagree) to 5 (strongly agree). The data collected were then analyzed using Excel and SPSS, utilizing nonparametric analysis methods. The percentage of social capital was determined using the formula in Eq. 1. The percentage scores were further categorized into five levels: very high (84-100%), high (68-84%), medium (52-68%), low (36-52%), and very low (20-36%). To enhance the analysis, interviews were conducted with 8 respondents in each area with stratified random sampling. Based on these data, descriptive strategies for poverty reduction were formulated (Eq. 1)

Score of Social Capital (%) =

$$\frac{average\ of\ all\ repondents'answer}{number\ of\ indicators \times score \max(5)} \quad (1)$$

RESULTS AND DISCUSSION

Social capital of underprivileged households in Enrekang Regency

Social capital acts as the adhesive that fosters unity and can create a functional social structure. Without internal coherence, a society is limited in achieving productivity and social welfare. Strong

Table 2: Social capital of underprivileged households in Enrekang Regency

Indicator	Rural-Agriculture			Urban-Multisector			P-value (Mann-Whitney)
	SD	Percentage (%)	Category	SD	Percentage (%)	Category	
Trust	3.68	90.97	Very high	2.6	81.33	High	0.000
Groups and Networks	10.01	77.40	High	10.97	38.75	Low	0.000
Norm and Collective Action	1.75	89.76	Very high	1.59	76.43	High	0.000
Information and Communication	1.87	91.03	Very high	2.03	86.04	Very high	0.003
Cohesiveness and Reciprocity	3.35	81.59	High	2.61	77.88	High	0.040

social networks facilitate the flow of information, which drives community development, and are reflected in the presence of trust, social norms, a sense of cohesion, and reciprocity (Hasbullah, 2006). Fig. 2 illustrates the mapping of social capital in underprivileged households in Enrekang Regency across two different areas.

The findings reveal that social capital is generally stronger in rural-agricultural areas compared to urban-multi-sector regions (Fig. 1 and Table 2). The results of the Mann-Whitney analysis also reveal significant differences between all indicators of social capital in the rural and urban areas. The trust index for underprivileged communities in rural areas is very high, with a percentage of 90.97%. This is notably higher than the trust level in the urban area, which stands at 81.33%. Groups and network dynamics in the rural area are categorized as high (77.40%), compared to the urban area, where they are considered low (38.75%). The norms of mutual assistance and collective action are very high in the rural area (89.76%) and high in the urban area (76.43%). Furthermore, both areas demonstrate very high information and communication infrastructure, with values above 86.04%, although access to information remains somewhat limited, often relying on government announcements, family, television, and the internet. Moreover, the cohesiveness and reciprocity indicators for the underprivileged society in both areas are high, at 81.59% and 77.88%, respectively.

Trust

Fig. 1 illustrates that the level of trust among the underprivileged community in rural areas is higher than in urban areas. This can be attributed to the presence of a kinship system, local institutions, religion, and traditional values prevalent in rural communities, which foster and sustain trust. Frequent interactions and the custom of exchanging greetings among community members help preserve strong kinship ties. In rural areas, trust grows naturally, thanks to the feeling of "neighbors are family." This is reinforced by the feeling of never being lied to and intimate interactions (we have intense communication, have chitchat, and meet often). In addition, social exchanges through various assistance strengthen the trust and the bond of residents. "The level of trust between residents is still strong, marked by the fact that there has never been a conflict. The people here consider their neighbors to be their family. The intensity of interaction is also a factor; if you meet someone quite often, you can judge the character of this person. Therefore, the more often we meet, the greater the level of our trust" (SDM-Man-Rural-Farmer). "The trust is built because we meet day and night, in our daily lives. So, if there is someone new, I tend to be hesitant because I do not know what the other are like" (MTH-Women-Rural-Farmer). This finding is supported by Coffe (2009), who concluded that community homogeneity has a profound effect on social capital formation. The homogeneity can enhance trust among group members, as shared views, values, and experiences create a sense of commonality (Coleman, 1988). Fukuyama (2001) also suggests that societal homogeneity tends to strengthen social bonds and foster greater social trust. It can reduce societal conflict, enhance social cohesion, and support political stability, as individuals are more likely to share common views on national identity, collective goals, and governance. This shared understanding

makes it easier for countries to implement effective policies. However, while homogeneity can strengthen social capital, the expert cautions that excessive homogeneity may stifle innovation and creativity. Highly homogeneous communities tend to prioritize internal relationships, creating a closed ecosystem that risks social isolation and limits opportunities to access resources, broaden perspectives, or leverage external opportunities. Therefore, it is crucial to strike a balance between managing homogeneity and embracing diversity to build social capital, especially in an increasingly diverse global context. Meanwhile, in urban-multisector areas, trust is not supported by close interpersonal relationships due to busy lifestyles and divergent interests. Issues of trust—particularly difficulties in trusting others—begin to surface as a result of personal experiences. Feelings of being marginalized based on social status make individuals become more selective in extending trust and often adopt a compromising stance by "pretending" to maintain harmonious relationships.

"We still believe in each other but have less interaction. Perhaps due to our own business" (RSM-Man-Motorcycle Taxis Driver-Urban Area)

Underprivileged communities in both research areas utilize trust-based social capital in various lending and borrowing practices or economic transactions. These activities typically involve borrowing necessities from local grocery stores, medicine, or agricultural fertilizers, cash, and even raw materials for resale. Such practices demonstrate how trust within the community activates social network resources to provide mutual support and reinforce the norm of reciprocity. However, some respondents expressed concerns that lending and borrowing can alter the dynamics of personal relationships, leading them to prefer maintaining positive social ties without financial entanglements. Additionally, borrowing is often associated with a sense of shame, particularly when repayment becomes difficult.

"For business capital, it is based on trust. We take vegetables from wholesalers at the market to sell at another market, and payment terms vary—some allow three days, some one week, and some require same-day payment by evening. If the payment is not yet sufficient, we settle it later" (SRT-Women-Vegetable Seller-Urban Area)

"Lending daily consumer goods is also commonly done when no more money exists. The mechanism is through a debt recording pattern without setting a repayment period limit, depending on our money availability. Likewise, for fertilizers or agricultural pesticides, when it comes to the fertilization time or spraying, but there is no money to buy, it is common to lending from agrochemical stores in the village" (ANY-Man-Farmer- Rural Area)

"For me, debts tend to be rare. I'm afraid to ask for money from others. That is why, if I have money, I keep it. I'm embarrassed to go begging" (HTJ-Women-Taylor-Urban Area)

Additionally, in rural areas, underprivileged households rely on trust within household and community relationships to engage in sharecropping and livestock raising through profit-sharing arrangements. This practice demonstrates how trust functions as an economic asset in everyday survival strategies. Further details are illustrated in the following interview excerpt.

"Livelihood activities are conducted entirely within the village and rely heavily on agriculture. We work on our land, and some of us cultivate land owned by others through a profit-sharing system. The cost of maintaining the crops is covered by the cultivator, while the crops themselves are provided and planted by the landowner" (ANY-Man- Farmer-Rural Area).

"We are still engaged in livestock farming through a profit-sharing arrangement with livestock owners to supplement our income. Under this system, the first calf is jointly owned by both the farmer and the livestock owner. When a second calf is born, the first calf becomes the property of the farmer, while the second goes to the owner. Since we lack the capital to purchase livestock, raising animals owned by others through this profit-sharing system becomes a practical alternative" (ANY-Man-Farmer-Rural Area).

Groups and networks

In the urban area, only 20 out of 77 respondents, or 25.97%, were involved in group activities, whereas in the rural area, 56 out of 63 respondents, or 88.89%, belonged to group activities. This indicates a tendency for the underprivileged society in the urban areas to underutilize group membership. This is likely due to the perceived high inequality in the socio-economic structure, which imposes mental burdens and creates barriers to group participation. Higher socio-economic status in urban areas significantly

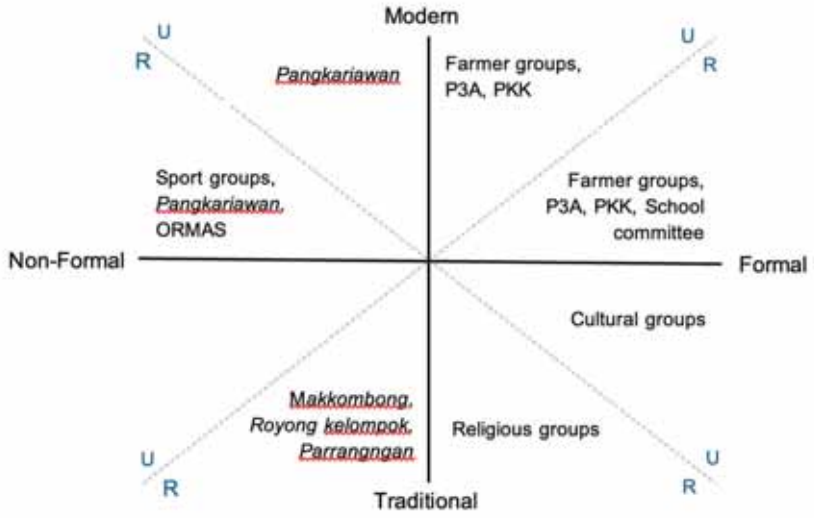

Fig. 3: Classification of groups among the underprivileged households in Enrekang regency; U (Urban areas), R (Rural area)

impacts access to group resources and networks. In contrast, communities in rural areas, characterized by their homogeneity and close kinship systems, do not view socio-economic differences as obstacles to group involvement. According to Musterd (2005), the homogeneity of neighborhoods in the Western industrialized world is evident in terms of socioeconomic status and ethnicity. Moreover, the homogeneity of rural areas is demonstrated by the relatively uniform income levels, with 81% of respondents in the very low category. This contrasts with the income distribution in urban multi-sector areas, where the income levels vary: 50% of respondents are in the low-income category, while the remaining 50% are distributed across the categories of no income, very low, and medium. Another indicator of homogeneity is the ethnicity of the respondents. In rural areas, 100% of respondents belong to the Massenrempulu ethnic group, whereas in urban areas, there are five different ethnicities. The social capital of groups and networks among underprivileged communities in rural-agriculture and urban-multi-sector remains predominantly at the bonding social capital level (fostering a sense of togetherness). It has yet to evolve into bridging social capital, which could effectively connect and utilize the community's broader potential resources. This is evident in the following characteristics:

(a) a high degree of homogeneity among group members, such as in religious study groups (shared religious affiliation), farmer groups (shared occupation), and neighborhood groups (shared residential area);

(b) Intergroup relationships are often goal-oriented and limited in scope, restricting the expansion of access to diverse services;

(c) Group funding primarily relies on self-contributions from members, reflecting strong individual responsibility for sustaining the group.

To foster bridging and linking social capital, it is essential to focus on building relationships that span across different social strata. Bridging social capital involves establishing connections with individuals from diverse backgrounds, positions, and interests—for example, by engaging in networks beyond one's immediate social circle, participating in activities that involve cross-group interaction, and joining initiatives that promote engagement across organizational hierarchies. By cultivating trust and relationships at multiple levels, individuals and communities can strengthen their social capital, thereby enhancing access to broader resources, information, and support systems. The characteristics of the groups observed in this study area are shown in Fig. 3.

Most people in rural areas remain engaged in traditional institutional practices. *Makkombong* groups, *royong* groups, and *parrangngan* are examples of informal traditional organizations characterized by

flexible membership and typically unwritten rules. In contrast, religious and cultural groups tend to be more formal, with defined memberships and both written and unwritten regulations. *Makkombong* is deeply rooted in values of togetherness and reciprocity, encouraging mutual assistance without expectation of compensation, driven by trust. In *royong* groups, however, assistance may be compensated—either fully or partially, as agreed upon by members—and typically supports communal goals, such as fundraising for mosques or youth initiatives. To ensure food security and protect crops from pests, rural communities also form *parrangngan* groups, which emphasize collective agricultural action. However, these traditions are in decline, particularly in urban areas, where individuals increasingly prefer to work as paid farm laborers (*pangkariawan* groups), viewing *makkombong* as inefficient in light of modern agricultural technologies that reduce the need for manual labor.

"The *makkombong* system has largely disappeared in residential areas, having been replaced by a wage-based labor system" (JML-Man-Farmer-Urban Area)

"The *makkombong* system no longer exists. It has been replaced by an employee system. At a glance, they may seem similar. Under the *makkombong* system, we provided food but no payment. In contrast, employees are paid but not provided with food" (SFL-Man- Farmer-Urban Area)

Gradual changes in the institutional structure of Enrekang society have the potential to weaken traditional institutional values. *Makkombong*, *royong*, and *parrangngan* groups are beginning to modernize without preserving the local wisdom inherent in these practices. The traditional institution of *makkombong* has experienced a shift in value with the rise of modern, formal agricultural-based institutions, such as farmer groups and P3A/GP3A groups. Additionally, the emergence of non-formal modern groups, like *pangkariawan* groups (farm laborers), which are driven by individual economic interests, further erodes the values of collective action within the community. This transformation is concerning as modern social structures are ideally meant to complement, rather than compete with, the pre-existing traditional social systems, which are rich in indigenous knowledge and wisdom. Changes in community institutions have raised concerns that the sense of togetherness is no longer formed organically but has become increasingly artificial. Institutions that once served primarily as socio-economic structures are now being transformed into economic-political entities that legitimize various activities aimed at advancing personal or group interests. As a result, the original socio-economic functions of these institutions are diminishing. In some cases, farmer groups have become sources of tension, with members feeling pressured or fearful when it comes to making political choices, often leading to internal isolation within the group. Furthermore, the growing phenomenon of excessive claims on group resources is becoming increasingly apparent, as certain individuals with privileged access to group facilities may inhibit other members from benefiting equally.

Norms and collective action

The social capital of norms has been integrated into the values of helping and collective action in the daily lives of the underprivileged community. These social capital norms, reflected in the willingness to help, ease of assistance, and participation in joint activities and customary practices, are more prominent among the respondents in rural areas rather than in urban areas (Fig. 1). The contrast between urban and rural communities is rooted in their social relationships and daily activities. In rural areas, close-knit relationships are shaped by a long-standing culture of cooperation, which continues to be reinforced through shared experiences and mutual dependence. Norms of collective action and mutual assistance are both the foundation and the outcome of social trust, sustained by strong feelings of kinship, mutual care, and protection. Conversely, urban communities—often marked by a more individualistic lifestyle—tend to show lower levels of community participation, as evidenced by weaker social bonds and diminished collective engagement. According to respondents, this individualism in urban areas is due to the diversity of individual occupations and personal routines, unlike rural communities, where occupational homogeneity, particularly in farming, fosters greater social cohesion and a stronger sense of community. However, the norm of mutual assistance tends to persist consistently throughout both the rural and urban areas. This phenomenon is most evident in community efforts during celebrations or crises, such as when a resident builds a house, where neighbors eagerly assist, whether

through labor or in-kind contributions like rice, sugar, and other necessities. Additionally, joint activities, such as irrigation maintenance through water user farmer associations (P3A/GP3A), *makkombong*, and *parrangngan* groups, remain common practices within these communities. According to Wahid *et al*., (2024), elements of social capital, such as networks and norms, underlie the interactions of farmers with various actors, including the village government, fertilizer distributors, agricultural extension officers, and others.

"Collective action and cooperation remain strong. For instance, during house construction, both men and women actively participate, with some contributing materials such as rice or sugar. Community members also engage in repairing irrigation systems, cleaning up garbage, and removing weeds, depending on the specific needs of the area" (SD-Man-Farmer-Rural Area)

Helping each other and cooperation—known as *makkombong*—are still very much alive. Support in the form of money continues to grow, especially during weddings, funerals, or when someone is ill. If a close family member is celebrating or facing a hardship, we usually bring items such as rice, cakes, coffee, and sugar. For more distant relatives or non-family members, assistance is typically given in the form of money" (SNY-Man-Farmer-Rural Area)

A slightly different phenomenon is observed in urban areas, where the tradition of helping with garden work has been replaced by paid laborers, known as *pangkariawan.*

Helping each other still occurs during family or neighbor celebrations and community events. However, mutual assistance in agricultural or personal activities has largely disappeared. Nowadays, individuals tend to work alone in their gardens, especially with the widespread adoption of the paid employee system. Mutual help is now more common in social and ceremonial contexts than in daily labor" (JML-Man-Farmer/Courier-Urban Area)

This study also finds a relationship between the ease of receiving help, readiness to offer assistance, and participation in collective action. The more easily community members can access help when needed, the more likely they are to engage in collective efforts and offer help to others (Cox, 1995; Jusniaty and Sani, 2018). This indicates that the underprivileged community tends to prioritize reciprocal norms over altruism within their social interactions. Additionally, certain underprivileged communities continue to participate in customary activities, highlighting that the social fabric of the Enrekang community still upholds traditional wisdom, including mutual aid.

Information and communication

One of the key pillars of social capital is an efficient flow of information and communication within the social structure to promote the development of community activities (Coleman, 1988). A low flow of information often leads to hesitation, causing people to refrain from taking action. Fortunately, all respondents in this study have access to electricity and internet services, making it easier to obtain information. Additionally, road infrastructure provides good transportation access, facilitating community mobility. Basic health and education facilities have been established in every village. This indicates that infrastructure development in rural areas is improving, approaching the level of progress seen in urban areas in Enrekang, although there remains a reliance on information from village governments via mosque announcements and family. Moreover, group information is commonly disseminated through WhatsApp groups. However, this method incurs additional costs for internet data, which not all underprivileged households can afford, thereby limiting their access to timely information.

"Information is usually received from the village head by being announced through mosques. Before our television (TV) broke, we usually got information from the TV media. Now, I often borrow my children's cellphones to access information" (SLT-Man-Farmer-Rural Area)

"Because face-to-face meetings are rarely held, the information is shared through WhatsApp groups. However, this method creates challenges due to the high cost of internet data, which limits each member's ability to access and share information effectively" (ARD-Man-Farmer-Rural Area)

Information shared within social networks often includes valuable insights and practical experiences that help individuals make better decisions. In many cases, underprivileged households may lack the specific knowledge needed to complete a task; however, by relying on their social networks, they can access useful references and guidance. This process is increasingly supported by internet connectivity, which allows individuals to gain new knowledge, access

training opportunities, and pursue self-development. As a result, social networks act as a catalyst, transforming social capital into human capital. This transformation not only benefits individuals but also strengthens the overall cycle of social networks.

"The existence of the gymnastics community (Kenko No Kai) greatly contributes to our access to health resources. We engage in routine gymnastics twice a week, and weekly checkups are provided. Additionally, we can consult with a doctor directly for free and receive valuable health information. Health updates are also occasionally shared during PKH group meetings" (HTJ-Women-Tailor-Urban Area)

"In addition to being part of the farmer group, I am also involved in a courier group. The courier group has been especially beneficial in ensuring smooth communication regarding delivery orders. We share delivery assignments when there are simultaneous orders, which helps optimize our work. So far, the courier community has been invaluable in helping set rates and provide information on the best delivery routes" (JML-Man-Farmer/Delivery Courier-Urban Area)

"Farmer groups also serve as a forum for exchanging information, such as issues with seeds, fertilizers, work challenges, or plant pests. For example, we often discuss pesticide-related concerns, sharing which ones are effective and which are not" (SLT- Man-Farmer-Rural Area)

In the field of development economics, it is noted that communities with access to symmetrical information tend to experience better development outcomes, as information about innovations is more widely diffused. Access to diverse information sources helps create "bridging social capital," which connects individuals from different backgrounds (Coffe, 2009). This type of social capital is crucial for accessing new ideas and resources, enhancing community resilience, and innovation.

Cohesiveness and reciprocity

Social cohesiveness and reciprocity are characterized by a collective spirit of cooperation, which fosters emotional bonds through the development of trust and is reinforced by strong social norms and values (Rahmadanih *et al*., 2021). In Enrekang Regency, the sense of togetherness and solidarity among the poor is primarily reflected in their participation in communal activities and their willingness to help each other. The high level of unity and solidarity forms the foundation for the value of reciprocity (the exchange of goodwill within the community). However, in urban areas, local institutional values have begun to decline, as evidenced by the diminishing practices of *makkombong*, *royong*, and *marrangngan*. In contrast, in rural areas, the sense of community remains strong enough to act as a safeguard against the influence of unwanted values. Overall, in rural-agriculture areas, the concepts of *makkombong*, *royong*, and *marrangngan* are still deeply ingrained in daily life. These concepts emphasize a sense of togetherness and mutual assistance, whether in cultivating agricultural land, eradicating pests, or participating in other social activities. The strength of this local wisdom is founded on mutual trust and the norm of reciprocity, which motivates individuals to engage in group activities. Reciprocity is a vital factor in gaining access to the most essential livelihood capital (Salman *et al*., 2021).

"The mutual assistance mechanism in the dominant farmer group takes the form of labor, not only during the land cultivation process but also occasionally during harvest. This practice is known as '*makkombong*' in the community. The *makkombong* system is organized by the group and takes place twice a week, on Wednesdays and Sundays, with members taking turns helping each other in cultivating agricultural land" (ARD-Man- Farmer-Rural Area)

Another indicator that reflects the cohesiveness and reciprocity is the frequency of conflicts within a community. This research shows that the level of conflict stemming from differences in characteristics tends to be low (29.31% in rural-agriculture and 29.09% in urban-multisector). This is likely due to the strong social capital within the community, which is demonstrated through high levels of togetherness, solidarity, and tolerance.

"Conflicts between residents are very rare. When they occur, it is typically due to differences of opinion and is usually resolved amicably, without escalating to the village government" (FTI-Women-Farmer-Rural Area)

"It can be said that conflicts are virtually non-existent; if they occur, they are resolved amicably. The conflicts that typically arise are related to land issues, but these are addressed peacefully by the

village authorities. In this community, none are alone; all are families" (SDM-Man-Farmer-Rural Area)

"When a conflict arises, one party typically gives in. We often choose to stay silent and avoid further trouble, as it's better not to escalate the situation" (HTJ-Women-Tailor- Urban Area).

Utilization of social capital by underprivileged households in Enrekang Regency

Woolcock and Narayan (2000) classify the typology of social capital into three types—bonding, bridging, and linking—to describe how individuals interact socially and access resources through group participation. Bonding social capital refers to the strong ties between individuals in similar situations, such as family members or neighbors. Bonding social capital in the research area enables underprivileged households access to informal financial resources, such as loans from family or friends, or credit for necessities from local kiosks. These financial supports help sustain productive activities and meet daily needs without leading to burdensome debt. Additionally, strong social ties facilitate the exchange of resources and mutual assistance, such as sharing food, business information, or helping one another during celebrations and important life events. Bridging social capital represents broader social connections beyond close family or neighborhood ties, including relationships with friends, co-workers, and members of other groups. For underprivileged households, bridging social capital facilitates the formation of business partnerships and participation in agricultural institutions, professional networks, or family associations. These wider social networks provide access to valuable resources such as information on economic opportunities, agricultural extension services, additional capital, risk-sharing mechanisms, and market access for their products or services. Moreover, farmer groups and P3A (Water User Associations) enhance agricultural cooperation through traditional collective work practices like *makkombong* (mutual labor exchange) and *mangpaleppa wai* (shared irrigation efforts). Moreover, linking social capital refers to connections between individuals or groups and institutions or individuals in positions of power and authority, often from different social backgrounds. These ties enable communities to access a wider range of external resources for collective benefit. For several households, linking social capital is realized through access to banking services, support from political parties, government assistance distributed via farmer groups, and funding from zakat collection agencies for business capital. The combined presence of bonding, bridging, and linking social capital is believed to strengthen household resilience by ensuring access to various forms of support, as illustrated in Table 3.

Portes and Landolt (1996) highlight that social capital can have negative effects if not properly managed. From a welfare perspective, such misuse can be highly detrimental. This study found that several farmer groups have been used as vehicles for economic and political practices that benefit only certain individuals or groups, while unfairly excluding others. For instance, at the bureaucratic level, a non-selective recruitment system for aid recipients is easily influenced by narrow interests rooted in personal or social ties. Similarly, the distribution of agricultural facilities and infrastructure assistance is often based not on the actual needs or management capabilities of the groups, but rather on shared political affiliations or social relationships. Portes and Landolt (1996) identify several negative consequences of social capital, as outlined below:

(1) Excessively strong social ties can lead to discrimination, undermining healthy competition, and excluding outsiders from equal opportunities. When access is engineered through "social ties," individuals who are not part of these networks are often prevented from participating or benefiting, regardless of merit or need.

(2) Excessive claims on group members can hinder individual progress. In some cases, individuals within a group may dominate due to greater access or influence, limiting the opportunities of others. Additionally, groups may suppress individual initiatives if they are perceived to conflict with collective interests, thereby restricting personal development and innovation.

(3) Strong group norms can lead to repressive social control. When norms within a group are overly rigid, they can restrict individual freedom and autonomy. This environment encourages constant peer monitoring, leaving little room for personal innovation or deviation from group expectations. As a result, members often face a dilemma between maintaining community solidarity and exercising individual freedom.

Table 3: Utilization of social capital by underprivileged households in Enrekang Regency

Research location	Utilization of social capital by underprivileged households
Rural-Agriculture	Bonding social capital
	a. Close family relationships serve as an alternative source of loans for business capital.
	b. Friend and neighbor networks provide access to plant seeds and various agricultural products for household consumption.
	c. Connections with fellow farmers serve as sources of information on agricultural commodities.
	d. Local staple goods stores offer informal credit for daily necessities.
	Bridging social capital
	a. Networks with agricultural supply stores enable access to pest control products or fertilizers on credit.
	b. Networks with intermediary traders (local collectors) facilitate the sale of agricultural produce.
	c. Interpersonal relations within agricultural institutions (e.g., farmer groups, women's farmer groups, and water user associations).
	Linking social capital
	a. Agricultural institutions (e.g., farmer groups, women's farmer groups, and water user associations) serve as platforms for accessing agricultural aid.
	b. Financial access through banking institutions for business capital loans.
	c. Political networks facilitate access to information and aid.
Urban-Multisector	Bonding social capital
	a. Family networks serve as sources of financial loans, educational assistance, and other forms of support.
	b. Friend and neighbor networks provide shared harvests for consumption, mutual aid during celebrations, misfortunes, or illnesses, assistance from wealthier residents, and information exchange.
	c. Local store networks offer informal credit for basic necessities.
	Bridging social capital
	a. Networks with vegetable suppliers from agro markets allow for trade credit arrangements.
	b. Business networks support the marketing of agricultural products.
	c. Vegetable vendors in local markets share leftover produce for consumption.
	d. Interpersonal relationships within farmer groups serve as platforms for information exchange.
	e. Participation in professional communities (e.g., motorcycle taxi and courier groups) provides access to job opportunities, customer information, routes, and fare setting.
	f. Kinship-based community networks facilitate the distribution of staple goods to members.
	Linking social capital
	a. farmer groups are utilized to access government assistance programs.
	b. Access to financial services through banks and cooperatives is used for capital loans.
	c. Political networks continue to facilitate access to information and aid.

(4) Downward leveling norms can suppress the weaker members of a group. While norms are intended to protect community members and foster unity, in an unequal group structure, they can become tools of exploitation. Weaker individuals may be pressured to conform in ways that limit their opportunities or well-being. Moreover, when group solidarity forms in opposition to the dominant or mainstream society, these norms can be used coercively, granting the group the power to control, marginalize, or even determine the survival of individuals or other groups under the guise of maintaining unity.

Designing social capital utilization for poverty reduction in Enrekang Regency

Social capital revitalization can be achieved through collaborative mechanisms with the following steps:

(1) The government contributes to strengthening social capital by providing physical infrastructure and financial assistance;

(2) The community maintains its social

Table 4: Design of social capital utilization in poverty reduction in Enrekang Regency

Rural-agriculture models
▪ The government's political will to use social capital as a support system for bolstering communities' innate ability to recognize problems and come up with creative solutions
▪ *Encourage the capacity of community elites in community advocacy to utilize existing potential*
▪ *Strengthening group capacity to expand collaborative networks with other groups, both internally and externally, in residential areas, including but not limited to shared goals*
▪ *Providing social capital incentives through increasing the allocation of social expenditure provided by the government and society for social activities*
▪ *Institutionalization of local practices as a social safety net: makkombong, group royong, jimpitan recitation, use of dasawisma and KWT yards, as well as health care groups*
Urban-multi-sector models.
▪ The development of social capital is directed at developing organizational capacity and building wider networks of cooperation and participation in the public sphere
▪ The existence of mediating institutions, such as mass organizations, political parties, and professional groups in the community with relatively well-educated human resources, can be empowered to bridge the aspirations of the community and the government in policy making (articulation of interests)
▪ Local government (at the neighborhood, sub-district, or district level) can develop public spaces that allow for more flexible social interaction between residents, for example, by building sports facilities, parks, markets, etc., so that there are no gaps or prejudices between residents of varying socio-economic status.
▪ Community groups who are relatively economically well off can be encouraged to participate by developing social partnership schemes to help provide public facilities that can be used together

relationships by adhering to norms of mutual help and actively engaging with one another.

Up to now, many government programs have not aligned with the principles of social capital development in poverty alleviation. These initiatives have largely focused on the short-term provision of basic individual needs, rather than prioritizing the long-term strengthening of social empowerment. The government has allocated village/sub-district funds and agricultural group assistance. However, there is a tendency for government funds to be focused more on operational costs and the maintenance of physical infrastructure, while investment in joint activities aimed at strengthening social capital is relatively neglected. Similarly, when communities adopt asocial behaviors and prioritize self-interest, it leads to a decrease in social spending for community activities. Both the community and the government have made efforts to invest in social capital, but these efforts appear to lack coordination. While communities have actively leveraged social capital in various initiatives, government programs continue to operate in isolation and are largely characterized by charitable, populist approaches aimed at garnering public support, rather than fostering sustainable empowerment. Therefore, a strong political commitment is needed to demonstrate the government's dedication to the community, particularly in increasing investment in the social sector, specifically through the revitalization of social capital, as part of efforts to support community empowerment programs and strengthen management groups. The social capital-based approach offers a valuable complement to economic strategies, emphasizing the importance of relationships, networks, and community support systems. When effectively utilized, social capital can expand individuals' access to critical resources such as knowledge, education, healthcare, security, and employment opportunities. Based on the social capital potential of the underprivileged community in Enrekang Regency, the design for utilizing social capital in poverty alleviation can be developed through two models

(a) rural-agriculture models; (b) urban-multi-sector models. The rural-agriculture model focuses on developing the internal capacity of the community (Table 4). This would enable residents to identify their needs and explore various alternatives to meet those needs using the potential resources. Additionally, it is essential to strengthen the managerial and leadership capacities of community groups so they can expand their networks both internally and externally. The government can play a role by facilitating the capacity-building of community leaders, enabling them to advocate for their communities and guide them in harnessing local potential. Strengthening incentives for social capital through social expenditure contributions

from both the government and the community is also crucial. Moreover, the institutionalization of local practices that bolster the social safety net, such as *makkombong*, *royong*, *marrangngan*, *jimpitan* in religious groups, PKK *dasawisma*, and health groups, can further enhance the effectiveness of social capital in poverty reduction. Furthermore, the design for utilizing social capital to reduce poverty in urban-multisector characteristics should focus on enhancing the capacity of community organizations, fostering cooperation networks between groups both internally and externally (beyond the local settlement), and strengthening participation in broader public spaces (Table 4). Urban-multisector areas are distinguished by the presence of various advocacy and mediation institutions, such as mass organizations, political parties, and professional associations, with relatively educated human resources that can serve to articulate the aspirations of the poor in government policy-making. Additionally, the spirit of *gotong royong* (cooperation), togetherness, and helping behaviors among residents needs to be revitalized by creating public spaces that allow for more flexible social interactions and collaborative activities. This would help reduce socioeconomic gaps and prejudices among residents of different backgrounds. Local governments and economically advantaged community groups can be encouraged to support the development of shared public facilities through social partnership initiatives.

CONCLUSION

This study defines social capital as a system of social relationships within a community, analyzed through two key perspectives. The first is the sociological perspective, which highlights how underprivileged households leverage social capital to cope with poverty. The research explores various dimensions, including levels of trust, the role of social norms, the effectiveness of social networks and groups, and community mechanisms that contribute to poverty alleviation. Findings reveal that social capital is primarily utilized to fulfill basic survival needs rather than to pursue profit maximization. Practices such as mutual assistance during farming activities (e.g., fertilization, planting, pest control), the sharing of harvests for collective consumption, and local kiosks providing loan mechanisms all demonstrate the vital role of social capital in sustaining daily life and reinforcing communal resilience. The second perspective is demographic, which examines the community's demographic conditions, particularly in terms of mobility and population composition (ethnicity, culture, and socio-economic background). This study focuses on the lowest decile of underprivileged households, specifically Family Hope Program (PKH) beneficiaries in Enrekang Regency. Research areas were classified into urban areas, characterized by diversity and multi-sectoral economic development, and rural areas, which are more homogeneous and primarily dependent on agriculture. The results show that components of social capital, such as trust, group networks, norms, information and communication, and cohesiveness, are significantly higher among the underprivileged community in rural-agricultural areas compared to those in urban-multisector communities. However, in both contexts, social capital remains largely at the bonding level—fostering internal solidarity—rather than bridging social capital, which would facilitate connections across different social groups and expand access to broader resources. Poverty reduction interventions based on social capital can be implemented at the micro level (families, neighbors, and local groups). These interventions should not only focus on inclusivity in policy-making but also on integrating marginalized individuals into socio-economically stable communities to form new, beneficial networks. This study has primarily focused on short-term poverty alleviation through increased access to social resources. Moving forward, there is a need for research that examines the long-term impact of social capital in poverty reduction, exploring how social networks, trust, and other forms of social capital contribute to sustained economic mobility. Additionally, further studies are required to understand how social capital supports resilience in the face of economic downturns, enabling individuals and communities to better overcome poverty. Another important aspect for future research is understanding how social capital functions differently among marginalized or vulnerable populations, including women, ethnic minorities, and refugees. Research can explore which forms of social capital (bonding, bridging, and linking) are most beneficial for these groups and how networks can empower them economically, socially, and politically. Equally important is conducting in-depth research on the

potential negative effects of social capital when it is poorly managed or exploited for narrow interests to benefit certain parties. Such situations can be highly detrimental from a welfare perspective.

AUTHOR CONTRIBUTIONS

A. Faisal performed the conceptualization, data curation, investigation, and writing- original draft. M. Saleh S. Ali, R. Rahmadanih, H. Ch. Lakare performed supervision, validation, review, and editing of the manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

Eq.	Equation
PKH	Family Hope Program
TV	Television

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