IJHCUM

Tehran Municipality

ISSN 2476-4698

Quarterly Publication

International Journal of Human Capital in Urban Management

Volume 9, Number 3, Summer 2024

Indexed by Scopus

International Journal of Human Capital in Urban Managemet (IJHCUM)

Publisher
Tehran Urban Research and Planning Center:
Tehran Municipality,
Tehran, Iran
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Printed at
Tehran Urban Research & Planning Publication Center

Indexed by Scopus

(QUARTERLY PUBLICATION)

Editorial Board

Publication authorization is certified by the Ministry of Cultural and Islamic Guidance; No. 77163; 14 March 2016

Urban Sustainability is Based on Human Capital

Circulation: 200

*p*ISSN 2476-4698 *e*ISSN 2476-4701

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International Journal of Human Capital in Urban Management (IJHCUM) aims to offer an outlook on the utilization of human capital in urban management based on existing urban and metropolitan problems. The journal expects to eventually turn into a convergence point as a reference available to professionals, managers and researchers in the field of urban management. Topics of interest include but are not limited to the following disciplines: Human Capital in Urban Management; Urban architecture, design, development and planning; Urban communications and services; Urban civil engineering and related management issues; Urban economics, administrative and financial management; Urban transportation systems and traffic management; Urban social and cultural welfare; Urban ecology and related; environmental concerns; Urban Health, Safety and Environment; Sustainable urban infrastructure.

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International Journal of Human Capital in Urban Management (IJHCUM) is an open access, peer-reviewed journal affiliated with Municipality of Tehran focusing on employment and allocation of human capital for urban management, including urban multidisciplinary themes. IJHCUM is an integral partner with the scientific and technical communities, delivering superior Information products and services that foster communication, build insights and enables individual and collective advancement in urban management. Providing human capital information to the general public administration with description of contemporary advances in urban issues to be used in improving protection and management.

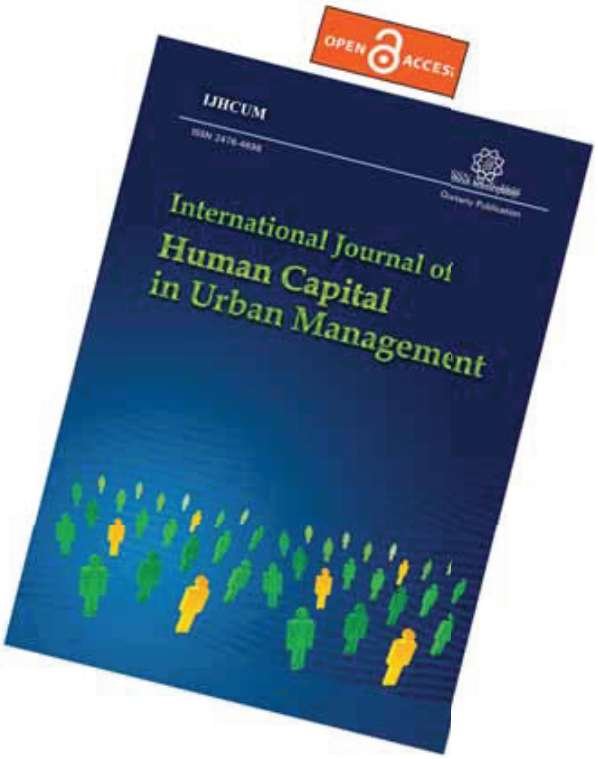
International Journal of Human Capital in Urban Management (IJHCUM)

Editor-in-Chief
E. Sheikh, Ph.D.

pISSN 2476-4698
eISSN 2476-4701

QUARTERLY FULL OPEN ACCESS PEER REVIEWED PUBLICATION

Journal Abbreviation: Int. J. Hum. Cap. Urban Manage.



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ORIGINAL RESEARCH PAPER

Lessons learned from urban crisis management system in COVID-19 pandemic using social network analysis

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ARTICLE INFO

Article History:
Received 02 September 2023
Revised 15 November 2023
Accepted 02 December 2023

Keywords:
COVID-19 pandemic
Crisis management
Organizational learning
Social network analysis
Tehran Municipality

ABSTRACT

BACKGROUND AND OBJECTIVES: Crises of high uncertainty and complexity provoke discussion about new requirements of crisis management systems, which is of utmost importance in developing a cooperative environment and providing effective responses. This study aims to analyze the cooperative system of Tehran Municipality departments involved in crisis management of the COVID-19 pandemic, who are called actors afterward and thereby present the lessons learned through this pandemic.

METHODS: Social network analysis has been applied in this research to analyze the collaboration system. Accordingly, the crisis management actions taken by Tehran Municipality are first explored and, 38 actors and 11 areas of knowledge are identified. The two-dimensional matrix of actors-actions and the cooperative system of the actors are then analyzed based on the degree and betweenness centrality indicators in UCINET and NetDraw software to investigate the position of the actors' tacit knowledge power in the cooperative network.

FINDINGS: The actors' cooperative system generally has high density and coherence; however, it seems that the position of some actors must be strengthened within the structure of the crisis management in Tehran Municipality. The results of the degree centrality index identified 7 actors with higher degree centrality (20% of total actors) and 7 actors with lower degree centrality (20% of total actors). Moreover, the betweenness centrality of the network of actors is analyzed to find the highest and lowest betweenness power in the cooperative network. Afterward, a series of recommendations are proposed based on a designed systematic intervention. Moreover, a cooperative system of pandemic crisis management would be developed based on the key actors' experiences and the lessons learned from failures.

CONCLUSION: Existing knowledge presents a valuable prospect for policy-makers in urban crisis management to establish an organizational cooperative system, capitalize on the insights gained, and contemplate pragmatic collective measures to enhance urban resilience in the face of pandemic crises.

DOI: 10.22034/IJHCUM.2024.03.01

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	4	2

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

The COVID-19 pandemic has exposed the vulnerability of urban life and urban performance to such an extent that most of the world's cities have long been in catastrophic chaos (Hassankhani *et al.*, 2021; Isaifan, 2020). Cities are often the focal point of the COVID-19 outbreak due to the high concentration of population and economic activity (Saedi *et al.*, 2022; Motaharian *et al.*, 2022). Accordingly, several researchers are striving to discover the dynamics of the pandemic in urban areas to perceive the impact of COVID-19 on city governance (Sharifi and Khavarian-Garmsir, 2020). The COVID-19 crisis has changed the face of many cities, raising questions about how one must manage urban life during a pandemic and the importance of learning from this in terms of city governance and urban crisis preparedness (Acuto, 2020). Municipalities around the world are considered a complex social system of city management as they provide a wide range of essential and basic services to citizens during a crisis such as the COVID-19 pandemic. Complex societies are better able to tackle complicated problems, provided that society's knowledge and information help to gradually reduce unfavorable systemic changes (Tabara, 2011). Crises with high degree of uncertainty and complexity place new demands on crisis management systems, and the development of a cooperative system between crisis management actors is crucial for an effective response (Chen *et al.*, 2019). In this respect, systems thinking is beneficial in dealing with complex situations and provides opportunities for collective action and learning from the crisis (Masys, 2015). Meanwhile, Social Network Analysis (SNA) is discussed as a social systems approach that aims to facilitate self-assessment of resilience in communities by bringing together actors to identify critical functions and vulnerabilities and to develop situational improvement activities. SNA provides important information about society's vulnerabilities to disasters and enables rapid identification of society's post-crisis sources of knowledge, which are useful for Crisis Information Systems (CIS) (Franco *et* al., 2013). Accordingly, this study uses social network analysis to explore the cooperative system of the COVID-19 crisis management in Tehran Municipality and presents the lessons learned from the development of the COVID-19 pandemic crisis management system as the first urban management experience in pandemic crises. The COVID-19 crisis identifies valuable lessons for sustainable urban planning and development. Moreover, the available knowledge provides an opportunity for decision-makers to take revolutionary actions in forming more just, more flexible, and more sustainable cities (Mejia-Dugand *et al.*, 2020). In this context, extensive research has evaluated the actions taken by municipalities in crisis management and salutary lessons have been learned by crisis managers. Clement *et al.* (2023) investigated the resilience strategies of the municipality in response to COVID-19 in Belgian cities. This study suggested that digital technology solutions can contribute to supporting the resilience of municipalities. Hassankhani *et al.* (2021) discussed a few lessons learned regarding smart cities and managing the COVID-19 pandemic. They analyzed the role of technology in crisis management and proposed policy recommendations appropriate for responding to the COVID-19 pandemic. Regarding the changes in social lifestyle and the ongoing shift from public transportation to private transportation, Corazza *et al.* (2021) evaluated urban management during the coronavirus pandemic and referred to the emergence of transportation policies and opportunities. Tori *et al.* (2023) studied the reactions of the public transportation sector to the COVID-19 pandemic in Belgium and recommended the structural use of foresight methodologies, such as scenario planning, to increase the preparedness of transport operators in the case of future disruptions. Ruszczyk *et al.* (2022) explored the lessons learned from urban health challenges during the coronavirus pandemic and discussed the considerations arising from the changing patterns of urbanization and the role of municipalities in maintaining urban health. Chen *et al.* (2021) examined changes in medical waste disposal technology as effective waste management measures in Wuhan, China during the COVID-19 pandemic. Peng *et al.* (2023) investigated the impact of measures to prevent and control the COVID-19 epidemic on citizens' satisfaction and suggested the timely release of epidemic information and the provision of basic health and medical services to citizens. Sharifi and Khavarian-Garmsir (2020) addressed the effects of the COVID-19 pandemic on cities and the lessons learned from urban planning, urban design, and urban management. They concluded that the improved quality of air and water

in cities over the periods of quarantine highlights the considerable environmental effects of human activities. Ahsan (2020) presented lessons learned from COVID-19 about the urban built environment and recommended that adequate provision of place, safety, and health-related issues in an integrated manner are needed to form a healthy urban built environment. Regarding an in-depth systematic review, Coccia (2023) demonstrated the importance of environmental factors in the spread of Coronavirus Disease 2019 (COVID-19), and demonstrated the associated aspects with public health, to provide lessons learned of health policy that can decrease the risks of emergence and diffusion of new pandemics with negative societal effect. Cardoso et al. (2023) examined the unsuccessful case of the Brazilian fiscal decentralization policy to help municipalities in fighting COVID-19. Gagliano et al. (2023) conducted a bibliometric analysis to find the research trends in the field of wastewater-based epidemiology (WBE) and provide a snapshot of the Lessons learned from the COVID-19 pandemic. Among the studies and lessons learned in urban management of the COVID-19 pandemic, an emphasis on community-oriented crisis management and the involvement of all stakeholders in crisis management can be found. In this context, Mejia-Dugand *et al.* (2020) explored many lessons learned from responses to the COVID-19 crisis in the cities of Bengaluru (India), Medellín (Colombia), and Cape Town (South Africa) to implement the sustainable development goals and indicated that strengthening multi-level governance and involvement of citizens and community in sustainable decision-making processes will play a critical role in managing cities around the world after the outbreak of Covid-19 (Mehia-Dugand *et al.,* 2020). He and Zhang (2022) investigated urban epidemic governance based on event system analysis on the COVID-19 outbreak and control in Wuhan, China and analyzed the system of Wuhan's COVID-19 response mechanism in four dimensions, including graded response systems, interactive relationship between multilevel entities of epidemic governance, quarantine regulations and the governance of public sentiment. Van den Oord *et al.* (2020) presented the lessons learned in Antwerp, Belgium about crisis management during the COVID-19 pandemic and found the significance of collective focus and integrity in creation and recreation of an effective crisis management system. They concluded that governance of organizational networks and involving the experts and planners are of utmost importance for revisiting the current design. Garavaglia *et al.* (2021) explored the challenges facing mayors in Milan, Italy during the COVID-19 pandemic and proposed some solutions on governance frameworks and institutions focused on involvement of volunteer groups and application of technology in sharing information on crisis management. Mirvis (2020) addressed the repercussions of the COVID-19 crisis management in the United States as learning from failures, analyzed the inadequacies regarding early warning, preparation, virus testing, coordination, communications and systematic challenges of the crisis and proposed recommendations on preparing for and responding to resembling crises in the future. Thielsch *et al*. (2021) discussed management of demands, sources and effective actions in multidisciplinary Crisis Management Teams (CMTs) and described the structuring of work processes, accurate, disciplined, predictive and purposeful communications and quick issue solution as especially effective actions taken by CMTs and presented it in an integrative model. Yan *et al.* (2023) designed consensus-reaching model in the social network environment for large-group emergency decision-making to managing non-cooperative behaviors. In a review of the studies conducted regarding disasters, Franco *et al.* (2013) examined the use of social network analysis in evaluating the possibility of cooperation and sustainability in response to social disasters and indicated how academic-social involvement can offer solutions for gaining more information on current relationships. Goswami *et al.* (2018) applied social network analysis in a disaster-struck society in the West Bengal state in India and analyzed the cooperative network of key actors through the various stages of the disaster. Based on social network analysis in the crisis management during the earthquake in China, Chen *et al.* (2019) examined the involvement mechanism of social organizations in emergency relief after natural threats and proposed policies for improving cooperation between social organizations and the government and enhancing the efficiency of emergency relief. On the assumption that knowledge exchange through stakeholder networks could effectively enhance absorption of innovation, Bojovic and Giupponi

(2020) revealed the potential of social network analysis in spreading and acceptance of innovations for managing disasters in Nepal and Kenya by applying social network analysis and discussed improving the role of network actors. Using the SNA approach, Jayasekara *et al.* (2021) analyzed the effectiveness of the actors' performance in planning to prepare for epidemics in Sri Lanka and referred to the dire need for an integrative legal framework and an efficient governance system for managing the risks involved in biological hazards in the country. Furthermore, they emphasized the expansion of the range of stakeholders involved in planning for preparedness and response to biological hazards, including the private sector, international development agencies, and non-governmental organizations. Adiyoso (2022) assessed governments' emergency responses to the COVID-19 outbreak using a social network analysis in Indonesia. Using the SNA approach and based on set time frames, Cho *et al.* (2022) analyzed Korea's response to COVID-19, with a focus on the network between the government and responding agencies. Es'haghi *et al.* (2022) evaluated the coordination of emergency response teams through social network analysis. Kannangara *et al.* (2022) explored the network of risk and crisis communication of government agencies in Sri Lanka during the early stages of COVID-19 through a social network analysis-based approach. Ilbeigipour and Teimourpour (2023) evaluated the relationship between the mobility network metrics and the COVID-19 outbreak through a social network analysis approach. Yao *et al.* (2023) evaluated urban resilience in the United States during the COVID-19 pandemic via social network analysis. Reviewing the literature reveals that the social systems approach has rarely received research attention in the COVID-19 pandemic management., Moreover, the network analysis of the pandemic crisis management is majorly limited to describing the whole network and its actors, and the cooperative system of the COVID-19 pandemic crisis management actors has been neglected. This study aims to analyze the cooperative network of the actors involved in the COVID-19 crisis management of Tehran Municipality as a complex social system through a process of systematic intervention using the SNA approach. After recording the urban managers' experience, the solutions are proposed for developing an epidemic crisis management system. The current study has been carried out in Tehran in 2022.

MATERIALS AND METHODS

In disaster research, social network analysis is applied where a system boundary can be defined, actors can be identified, and their relationships can be recognized (Goswami *et al.,* 2018). In SNA, the relationship network of social actors is calculated using the UCINET software based on the graph theory and network centrality concepts, and the network is drawn and analyzed by utilizing the Net Draw software (Hanneman *et al.,* 2012). This study analyzes the cooperative network of the COVID-19 crisis management in Tehran Municipality. For this purpose, the actions are classified into 11 crisis management knowledge areas according to the reported actions of the organizational units involved in the COVID-19 crisis management. Fig. 1 illustrates the actions declared in the reports of the COVID-19 crisis management headquarters by distinct knowledge areas. It depicts that the majority of actions can be classified in the knowledge area of medical and preventive services, public urban services, cultural services and social support, and transportation and traffic services.

To identify the relationships of the actors in the cooperative network, based on the actions taken in knowledge areas, the actors-actions matrix of the COVID-19 crisis management headquarters of Tehran Municipality is then considered as a two-dimensional network. The entries of this matrix are the number of declared actions of actors in each knowledge area. Table 1 presents the symbols of the knowledge areas and Table 2 presents the symbols of the responsible and partner organizational units of the COVID-19 crisis management headquarters. The analysis of the network matrix data is done using the UCINET software and the graphs are drawn using the NetDraw software. The cooperative network includes 38 actors and 11 knowledge areas and the relationships between two nodes in this network is to indicate that an action is taken by the actor in that area. Fig. 2 illustrates the actors-actions network of the COVID-19 crisis management in Tehran Municipality.

RESULTS AND DISCUSSION

To analyze the cooperation network of the COVID-19 crisis management system, a one-dimensional data set of actor-to-actor relationships

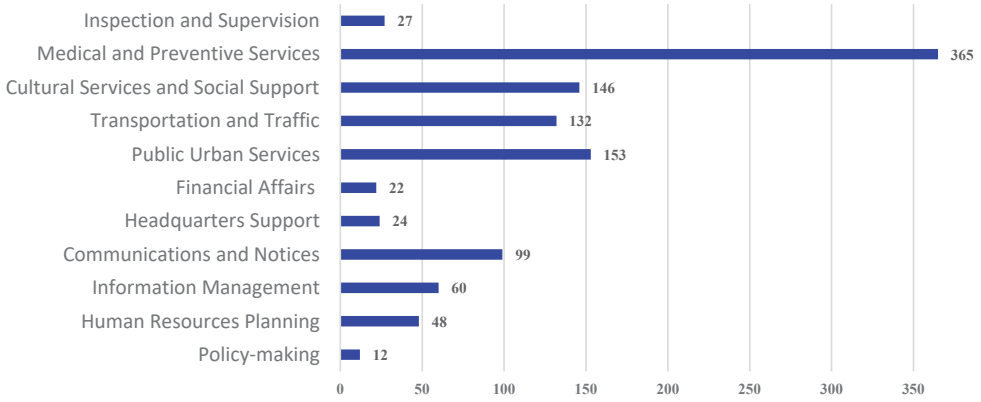

Fig.1: Classification of the COVID-19 crisis management actions

Table 1: Symbols of Actions in the Actors-Actions Network Matrix

Symbol	Knowledge Area	Symbol	Knowledge Area
ACTG 01	Policy-making	ACTG 07	Public Urban Services
ACTG 02	Human Resources Planning	ACTG 08	Transportation and Traffic
ACTG 03	Information Management	ACTG 09	Cultural Services and Social Support
ACTG 04	Communications and Notices	ACTG 10	Medical and Preventive Services
ACTG 05	Headquarters Support	ACTG 11	Inspection and Supervision
ACTG 06	Financial Affairs		

Table 2: Symbols of Municipal Departments in the Actors-Actions Network Matrix

Symbol	Municipal Department	Symbol	Municipal Department
ORG 01	Tehran Disaster Mitigation and Management Organization (TDMMO)	ORG 02	Deputy of Planning, Human Resources Development and Councils Affairs
ORG 03	Office of Planning Monitoring, Project Control, and Performance Evaluation	ORG 04	Municipality Districts Affairs and Coordination
ORG 05	Administrative Office of Human Resources	ORG 06	Administrative Office of Budget
ORG 07	ICT Organization	ORG 08	Tehran Urban Research & Planning Center
ORG 09	Communications and International Affairs Center	ORG 10	Tehran Municipality Protection Unit
ORG 11	Tehran Municipality HSE System	ORG 12	Urban Financial and Economic Department
ORG 13	Administrative Office of Financial Affairs and Properties	ORG 14	Administrative Office of Support
ORG 15	Administrative Office of Technical and Civil Coordination of Organizations and Districts	ORG 16	Administrative Office of Urban Services
ORG 17	Tehran Fire Department	ORG 18	Waste Management Organization
ORG 19	Tehran Municipality Management of Fruit and Vegetables Organization	ORG 20	Shahrvand Chainstore Co.
ORG 21	Shahrban Company	ORG 22	Tehran Gardens and Green Spaces Organization
ORG 23	Occupations and Industries Organizing Company	ORG 24	Behesht Zahra Organization
ORG 25	Deputy of Transportation and Traffic	ORG 26	Tehran Urban & Suburban Railway Company
ORG 27	Tehran and Suburbs Bus Company	ORG 28	Taxi Management and Supervision Organization
ORG 29	Bus Terminals Organization	ORG 30	Social and Cultural Affairs Department
ORG 31	Retirees Organization	ORG 32	Sport Organization
ORG 33	Tehran Municipality Basij	ORG 34	Administrative Office of Health
ORG 35	Shahre Salem Company	ORG 36	Ministry of Cooperatives Labor and Social Welfare
ORG 37	Administrative Office of Isargaran's Welfare Affairs	ORG 38	Inspection Organization of Tehran Municipality

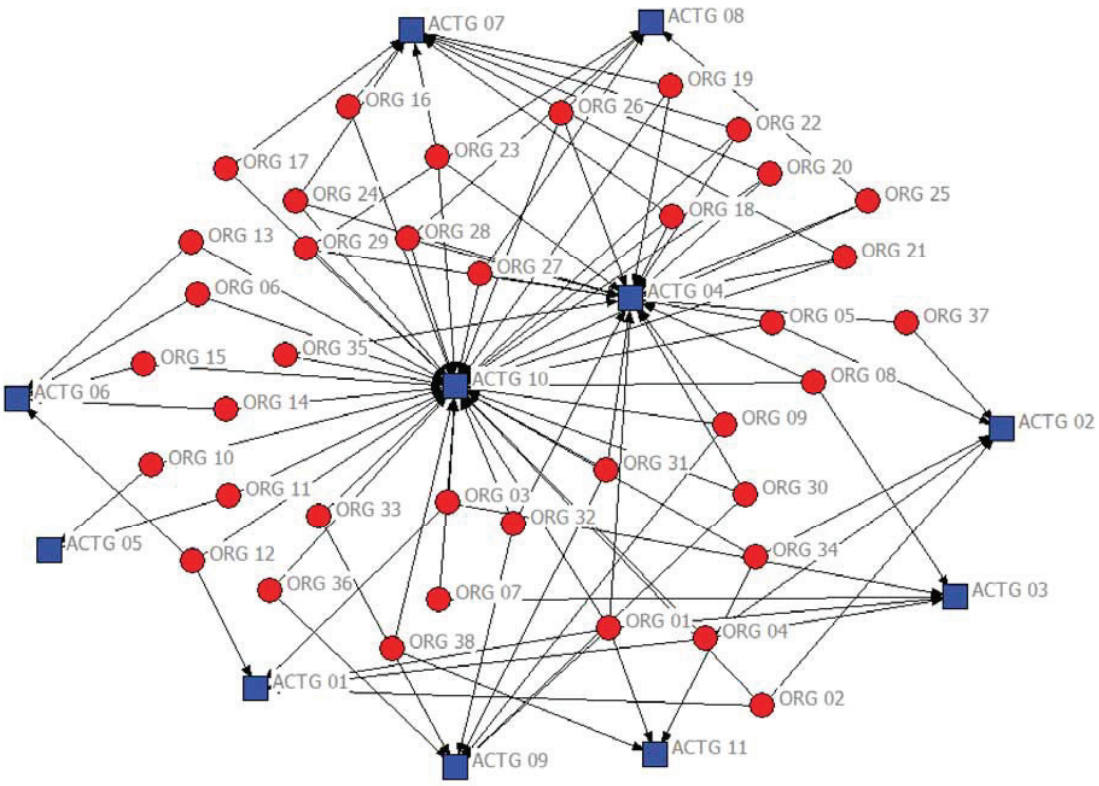

Fig.2: Actors-Actions Network of the COVID-19 Crisis Management in Tehran Municipality

is generated based on the two-dimensional actors-actions data, and the one-dimensional actors-actors network is analyzed based on network analysis indexes. Considering the role of actors in the cooperative system, a combination of actors with high and low degree centralities and high betweenness centrality, including 10 senior managers, is selected and their managers' experiences are recorded through some semi-structured interviews. The managers are asked to describe their experiences of success and failure to record and extract tacit knowledge. The findings of network analysis and the lessons learned from the key actors' experiences during the COVID-19 crisis management in the Municipality of Tehran are as follows. The actor-to-actor relationships dataset is generated based on the two-dimensional actor-action data. This dataset assesses the strength of the relationships between each pair of actors based on the frequency with which the actors take similar actions in each knowledge domain of crisis management. This value is summed for the action groups of 11 knowledge areas of crisis management and was considered as an actor-actor matrix entry. Accordingly, the cooperative network of the actors is analyzed in the UCINET software and drawn in the NetDraw software based on the degree centrality indexes and the betweenness centrality. Table 3 presents the degree of centrality and the betweenness centrality of the actors' cooperative network in the COVID-19 crisis management in Tehran Municipality.

The degree of centrality index results reveal that some actors possess a greater degree of power than others involved in the cooperative network of the Municipality's COVID-19 crisis management. According to the degree centrality index, 7 actors with a high degree centrality (20% of total actors) are identified as high-power actors in the cooperative network, including Shahre Salem Company (ORG 35), Deputy of Transportation and Traffic (ORG 25),

Table 3: Degree centrality and betweenness centrality of the cooperative network of the actors in the COVID-19 crisis management in the Tehran Municipality

Actor	Degree Centrality	Betweenness Centrality	Actor	Degree Centrality	Betweenness Centrality
ORG 01	33.054	1.714	ORG 20	160.324	1.217
ORG 02	23.757	1.217	ORG 21	63.432	1.217
ORG 03	27.811	0	ORG 22	65.486	1.217
ORG 04	91.486	1.217	ORG 23	121.351	1.217
ORG 05	79.405	1.217	ORG 24	153.270	1.217
ORG 06	11.297	0	ORG 25	317.270	1.217
ORG 07	118.919	0	ORG 26	178.297	1.217
ORG 08	40.351	1.217	ORG 27	247.189	1.217
ORG 09	129.243	1.217	ORG 28	215.378	1.217
ORG 10	68.811	0	ORG 29	167.108	1.217
ORG 11	97.027	0.235	ORG 30	243.676	1.312
ORG 12	51.811	0	ORG 31	47.324	1.217
ORG 13	11.297	0	ORG 32	175.946	1.217
ORG 14	20.649	0	ORG 33	174.378	0
ORG 15	22.054	0.602	ORG 34	18.703	1.217
ORG 16	13.946	0	ORG 35	846.892	1.714
ORG 17	81.946	0	ORG 36	69.568	0
ORG 18	191.514	1.217	ORG 37	6.622	0
ORG 19	171.676	1.217	ORG 38	30.270	0

Tehran and Suburbs Bus Company (ORG 27), Social and Cultural Affairs Department (ORG 30), Taxi Management and Supervision Organization (ORG 28), Waste Management Organization (ORG 18) and Tehran Urban & Suburban Railway Company (ORG 26). Furthermore, 7 actors with a low degree centrality (20% of total actors) are identified as actors with a low degree of power in the cooperative network, which include Administrative Office of Isargaran's Welfare Affairs (ORG 37), Administrative Office of Financial Affairs (ORG 13), Administrative Office of Budget (ORG 06), Administrative Office of Urban Services (ORG 16), Administrative Office of Health (ORG 34), Administrative Office of Support (ORG 14), Administrative Office of Technical and Civil Coordination of Organizations and Districts (ORG 15). Fig.3 is an illustration of the cooperative network of the actors involved in the COVID-19 crisis management in Tehran Municipality.

In addition to the degree centrality index, the betweenness centrality of the network of actors is analyzed. Fig.4 depicts the cooperative network of the actors involved in the COVID-19 crisis management in Tehran Municipality based on the betweenness centrality index. The size of each node is indicative of the betweenness centrality for each actor. The actors possessing the highest and lowest degrees of betweenness power with other actors in the cooperative network are identified based on the betweenness centrality index. Those with the highest betweenness power in the cooperative network of the actors involved in the crisis management of the Municipality of Tehran were the Tehran Disaster Mitigation and Management Organization (ORG 01), Shahre Salem Company (ORG 35), Social and Cultural Affairs Department (ORG 30). The actors identified with the lowest betweenness centrality in the cooperative network of the actors involved in the crisis management of the Municipality of Tehran are the Urban Financial and Economic Department (ORG 12), Ministry of Cooperatives Labor and Social Welfare (ORG 36), Administrative Office of Isargaran's Welfare Affairs (ORG 37), Administrative Office of Financial Affairs and Properties (ORG 13), Administrative Office of Budget (ORG 06), Office of Planning Monitoring, Project Control and Performance Evaluation (ORG 03), Inspection Organization of Tehran Municipality (ORG 38), ICT Organization (ORG 07), Administrative Office of Support (ORG 14), Tehran Fire Department (ORG 17) and Administrative Office of Urban Services (ORG 16).

It can be generally stated that the cooperative network of the actors involved in the crisis management of Tehran Municipality enjoys great density and coherence so that all the actors cooperated in the group of actions of the COVID-19

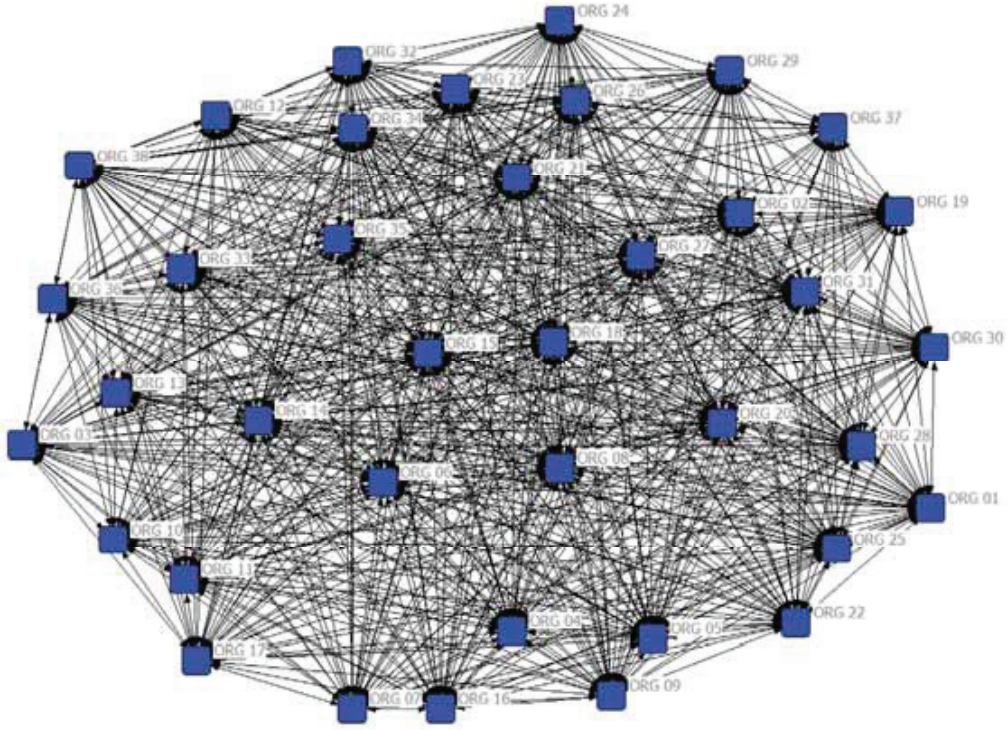

Fig.3: Cooperative network of actors involved in the COVID-19 crisis management in Tehran Municipality based on degree centrality index

crisis management. Nonetheless, considering the key positions of some actors in crisis management, they must be given more power in the structure of the COVID-19 crisis management. As the results of the degree centrality and the betweenness centrality indicate, the actors of the financial and economic provision have low power in the cooperative network. Thus, effective measures must be taken regarding the budget and financial resource management to expand the cooperative network. On the other hand, actors such as Municipality ICT organizations, Office of Planning Monitoring, Project Control and Performance Evaluation, and Inspection Organizations have low betweenness centralities despite their acceptable degree of centrality. Given the role and importance of performance management in greatly uncertain situations, such as the COVID-19 crisis, where the quality of the decisions made by organization senior managers depends on up-to-date and accurate information on the crisis, these actors' power positions within the network must be improved.

Lessons learned

To recognize the instances of success and examples of probable failures, the managers of the key actors, a combination of actors with high and low degree centralities and high betweenness centralities, have been interviewed. Then the most prominent successes of COVID-19 pandemic crisis management in Tehran Municipality are discussed and the lessons learned from failures are addressed afterward. Finally, some suggestions about developing a cooperative system of key actors are made based on the relative agreement of these actors.

Learning from successes

• *Attention to early international warnings and timely response*

Concentrating on the early warnings of the pandemic in the world and following up the international studies led to the proper preparedness of Health Care departments of Tehran Municipality for a timely response to the outbreak of the pandemic in the city. Compilation of specific instructions, provision

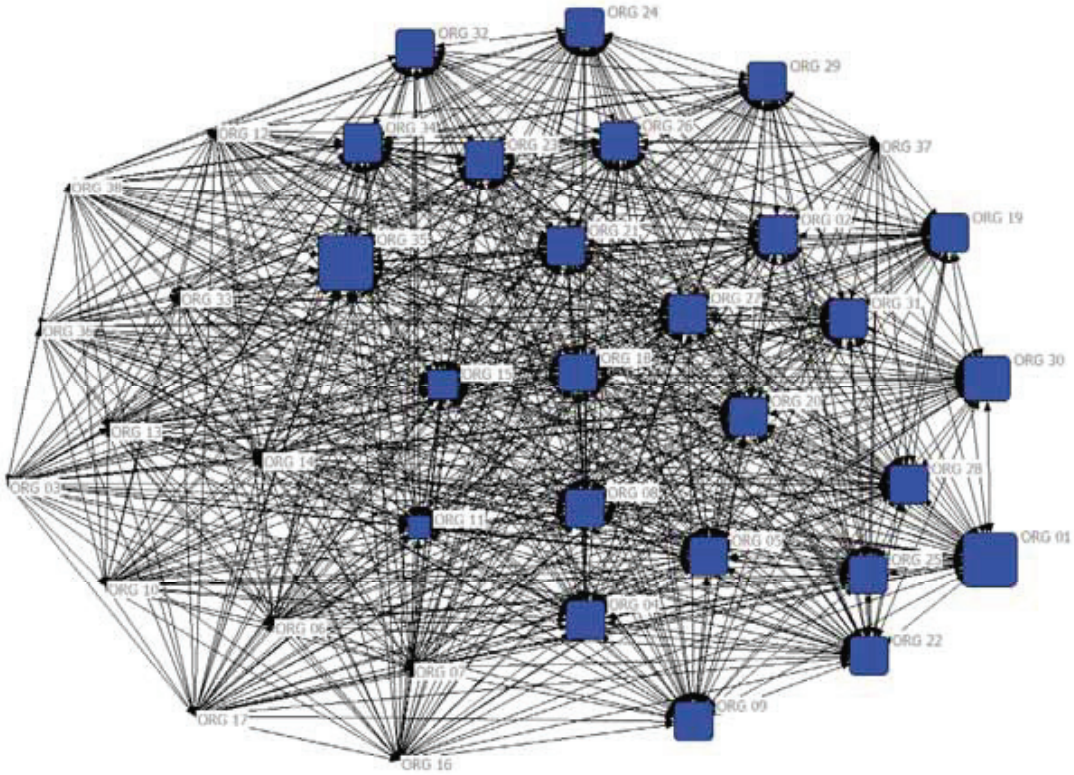

Fig.4: Cooperative network of actors involved in the COVID-19 crisis management in the Municipality of Tehran based on the betweenness centrality index

of administrative and scientific mechanisms, ongoing implementation of COVID-19 screening initiatives on Tehran Municipality staff, allocation of Tehran Municipality clinics in different districts to the COVID-19 patients, and 24/7 activity of some Tehran Municipality medical centers during the COVID-19 crisis peaks are some of the successful experiences of the COVID-19 pandemic crisis management in Tehran Municipality.

• *Volunteer attendance in vaccination*

At the beginning of vaccination, when the vaccination centers of the Ministry of Health were inadequate and long queues were formed, Tehran Municipality began vaccinating a wide range of Tehran citizens by establishing vaccination centers, including mosque vaccination centers, subway station vaccination centers, and vaccination buses known as the "Life Bus".

• *Development of a special vaccination service for vulnerable or disabled citizens*

During the coronavirus pandemic, mobile vaccination centers provided vaccination services to vulnerable groups, such as foreign citizens, working children, addicts, disabled, and elderly people, at their residences. Vaccination of these vulnerable groups is considered one of the most prominent actions taken by the Municipality of Tehran in managing the COVID-19 crisis, with emphasis on respecting human dignity and the citizens' welfare, as well as the acceleration of vaccination.

• *Society-oriented involvement of public volunteer forces*

Society-oriented involvement of public volunteer forces during the COVID-19 crisis is considered by Tehran Municipality as another successful experience of crisis management. Participation in vaccination

initiative conducted by the Municipality of Tehran, cooperation in providing crisis management training at schools, participation in relief maneuvers and local and regional rescue training, cooperation in holding public crisis management training in the neighborhoods, involvement in the neighborhood-oriented screening plan, and provision of social support services are only some instances of the actions taken by public volunteers during the COVID-19 pandemic.

• *Acceleration of smart city development by expanding IT and communications infrastructure*

The COVID-19 outbreak necessitated the provision of electronic services and the infrastructure established for staff telecommuting can also accelerate the smart city development in Tehran. Considering the role of information technology in crisis management, Tehran's smart city plan must be implemented more seriously and its electronic services must be strengthened and expanded for the resilience of the urban management system.

Learning from failures

• *Delay in activating the Incident Command System*

The lack of a comprehensive plan for managing all types of crises is one of the basic deficiencies of the country's crisis management, which led to a lack of prior planning for taking advantage of the existing potentials and capacities; therefore, despite the preparedness of many Tehran municipal organizations and people to provide services in the COVID-19 pandemic crisis management, the capacities and potentials were not utilized efficiently. It is suggested that at both national and Tehran levels, the roles and relationships of every single organization, involved in the incident command system, be determined; the rules and regulations of the country's crisis management be revised; and the scope of responsibility and authority of the key actors be clarified.

• *Delay in providing financial resources*

Due to the considerable reduction in income and imposition of new costs, the COVID-19 crisis affected Tehran Municipality's financial situation considerably. Given inadequate funding, supplying credits and making payments happened with delays, which resulted in demotivating some working units. Although the mechanisms of funding and budget allocation are addressed in the country's disaster management law, the executive guarantee in this regard proves challenging. It is recommended that not only should legal approvals be sought regarding the funding of Tehran's crisis management, but also necessary measures be taken for granting the associated budget to the commander and the crisis managers. In addition, to anticipate and reduce the costs of providing urban services during a crisis, value engineering is recommended.

• *Underutilization of the provided capacity by public volunteer forces*

Reports indicate that only a portion of the volunteers was employed in managing the COVID-19 crisis. Managers attribute this underutilization to the fact that the nature of the epidemic crises is completely different from short-term crises, such as floods and earthquakes. Given the length of the COVID-19 pandemic, it was not feasible to provide long-term volunteer services and the volunteer groups could not be considered as the main human resources for crisis management. It seems that to apply the maximum capacity of the volunteers in the long-term process of epidemic crisis management, a thorough analysis must be conducted in advance. Accordingly, for the sake of organizing and integrating volunteers, it is recommended to make arrangements with the Iranian Red Crescent Society as the main administrator of supplying public volunteer forces and other related institutions and plan for using public volunteer forces in managing different sorts of crises based on the volunteers' database.

• *Inaccessible data and analysis tools*

In the planning phase of the COVID-19 crisis management, sufficient information and analysis tools were not provided to the decision-makers in proper time and the designed information dashboards could not help operational planning promptly. It is suggested to have a strategic plan for improving the data accessibility and analysis tools to be able to respond more efficiently and effectively in times of crisis.

• *Failure to impose restrictions on public transportation*

Aiming to prevent the spread of COVID-19

by refusing the entry of unvaccinated people to the public transportation system, the crisis management headquarters of Tehran Municipality could not succeed in accessing the citizens' vaccination information system. This was mainly due to a lack of information integrity and a deficit in inter-organizational cooperation. Considering the importance of accessibility of databases to the management system and despite the existence of some databases, it is suggested to identify the required databases for managing all types of urban crises and integrate the information systems of urban crisis management.

• *Lack of efficient scenario-based planning for human resource management*

Since there were no prior rules or regulations related to the employee's attendance during the COVID-19 outbreak and the municipal employees were not culturally ready for telecommuting, some restrictions were imposed. Moreover, some profitable activities/services of the municipality had ceased to prevent the rapid spread of coronavirus and there was no planning for their employees. Therefore, it is worth reviewing and revising the human resource rules and guidelines to determine and adapt the policies and procedures for human resource management in crisis.

• *Failure to document*

Although Tehran Municipality presented some valuable documents and reports on the COVID-19 crisis management, not all of the weaknesses and deficiencies were explicitly addressed. Regarding the fact that the realistic pathology of Tehran Municipality's crisis management system requires the use of scientific methods of crisis documentation and reporting, it is suggested to implement critical analyses by using the key actors' experiences, in addition to documenting and recording. As mentioned in the introduction, the previous research mostly focused on a single aspect of the effects the pandemic had on urban management. For instance, Hassankhani *et al.* (2021) mentioned various technology-driven policies and actions could help manage crises, enhance the well-being of the community, and increase urban resilience. Corazza *et al.* (2021) noted that regarding transport policies, the lesson of the pandemic highlights inequality and leaves opportunities only for the more affluent citizens. Chen *et al.* (2021) discussed the great difficulty that COVID-19 posed for the medical waste disposal system of Wuhan. Ruszczyk *et al.* (2022) stated COVID-19 believed that the pandemic has worsened the current challenges of climate change, urbanization, and the changes in local government. Tori *et al.* (2023) focused on the public transport operators in Belgium, who see COVID-19 as a learning platform to get ready for future crises. Ahsan (2020) mentioned centralized decision-making and active participation and implementation at the local level as a way to deal with the pandemics, such as COVID-19. However, a small number of papers considered the issue generally; for example, Garavaglia *et al.* (2021) discussed the challenges that the mayors of Milan faced during the COVID-19 pandemic and proposed some solutions. The current study considers the effects of the pandemic on urban life from a general point of view and tries to extract the learned lessons by considering the overall perspective.

CONCLUSION

COVID-19 has further highlighted the deficiencies of urban management and has provided a unique opportunity to rethink, replan, and redesign urban management. The lessons learned from the urban management of the COVID-19 crisis cannot be ignored due to the quarantined urban dwellers, the besieged cities, the recession, and most importantly and unfortunately, the loss of citizen lives. Municipalities are considered a social system of city government as they provide a variety of essential and basic services to citizens in crises. Since success in delivering a system's services requires the coordination and coherence of social interactions between subsystems, it is important to create a collaborative system between crisis management actors. This study analyzed the cooperation system of COVID-19 crisis management actors in the city of Tehran by using SNA and presented the lessons learned from the development of the COVID-19 pandemic crisis management system in Tehran Municipality, as an instance of the first urban management experience regarding the pandemic crisis. Accordingly, 38 actors were identified and classified into 11 knowledge areas by examining the reported actions of the COVID-19 crisis management in the Municipality of Tehran. The network of actors was then analyzed, a systematic

intervention was introduced to select high and low-centrality actors and the key actors, and a series of recommendations were proposed. The aim of this study is not only to expand the existing knowledge on pandemic crisis management in municipalities but also to provide a suitable background for future research. Since the topical issue is defined within the framework of Tehran city's COVID-19 crisis management system, future research can expand the scope of social crisis management analysis and analyze the views of citizens and stakeholders outside Tehran city in the cooperative network of COVID-19 crisis management. Furthermore, given the existing challenges at the governance level of crisis management, it is recommended that future research evaluates the governance structure of crisis management based on the country's disaster management laws and analyzes crisis participatory governance balancing solutions based on the distribution of legal power among the actors of the current structure of the country's crisis management and the theory of participatory governance of crisis management.

AUTHOR CONTRIBUTIONS

M. Samadi-Foroushani performed the literature review, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. S.S. Miresmaeeli and Z. Molamohammadi compiled the data and manuscript preparation. A. Nasiri conceived the idea and reviewed the manuscript.

ACKNOWLEDGEMENT

This study was supported by the Project Support Program for the Tehran Urban Research and Planning Center and the Tehran Disaster Mitigation and Management Organization (TDMMO). [Project number 137/1132213]. We are grateful for the cooperation of all participants in Tehran Municipality.

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, falsification, double publication, submission, and redundancy, have been entirely witnessed by the authors.

OPEN ACCESS

PUBLISHER'S NOTE

ABBREVIATIONS

ACTG	Action Group
CIS	Crisis Information Systems
CMTs	Crisis Management Teams
ICT	Information and Communications Technology
ORG	Organization
SNA	Social Network Analysis
TDMMO	Tehran Disaster Mitigation and Management Organization

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HOW TO CITE THIS ARTICLE

Samadi Foroushani, M.; Miresmaeeli, S.S.; Nasiri, A.; Molamohamadi, Z., (2024). Lessons learned from urban crisis management system in COVID-19 pandemic using social network analysis. Int. J. Hum. Capital Urban Manage., 9(3): 375-388.

DOI: 10.22034/IJHCUM.2024.03.01

URL: https://www.ijhcum.net/article_709254.html

Int. J. Hum. Capital Urban Manage., 9(3): 389-404, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

The impact of implementing green human resources practices on employee engagement sustainability

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ARTICLE INFO

Article History:
Received 18 August 2023
Revised 15 October 2023
Accepted 21 December 2023

Keywords:
Employee engagement sustainability
Green training and development
Green recruitment and selection
Green compensation and reward
Malaysian food and beverage Industry

ABSTRACT

BACKGROUND AND OBJECTIVES: Malaysia's food and beverage industry provides a diverse range of regional and global cuisines, reflecting the country's diverse population. Profit, the development of new products, customer and employee satisfaction, and the sustainability of employee engagement have an impact on an organization's productivity. Positive attitudes towards green human resources management—which encompasses green hiring and selection, green training and development, and green remuneration and reward—are a sign of engaged employees. Businesses in this industry found it difficult to retain employees due to insufficient green hiring and selection procedures, inadequate training and development programs, and insufficient compensation and benefits. This research examines the relationship between green training and development, green recruitment and selection, and green compensation and reward for employee engagement and sustainability in the Malaysian food and beverage industry.

METHODS: For this investigation, the quantitative method was used to analyze information using IBM SPSS software version 26. The objective was to improve the industry's efficient functioning for long-term growth. A total of 210 surveys were distributed to Klang Valley workers in this industry using convenience sampling and a non-probability sampling approach. Taro Yamane's approach was used to calculate the sample size. Convenience sampling is a non-probability sampling technique where sample units are selected based on their accessibility to the researcher.

FINDINGS: As a result, all three variables- green training and development, green recruitment and selection, and green compensation and reward- have a positive and significant relationship with employee engagement sustainability. The hypotheses have been accepted with a p-value ranging from 0.000 to 0.236. In the case of hypothesis 1, there is a positive correlation ($r = 0.760$, $p \leq 0.01$) between green training and development and employee engagement sustainability. Similarly, hypothesis 2 shows a positive correlation with a significant p-value of 0.236 between green recruitment and selection and employee engagement sustainability. Hypothesis 3 also indicates a significant correlation ($r = 0.762$, $p \leq 0.01$) between green compensation and reward and employee engagement sustainability.

CONCLUSION: The study provides empirical evidence and conceptual proof that the establishment and management of a fund designed to promote the development of human resources within a specific jurisdiction are governed by the Pembangunan Sumber Manusia Berhad Act of 2001. The interaction between this act and Green Human Resource Management may differ depending on the specific laws and policies of a country or region. Organizations can utilize funds from the Human Resource Development Corps to carry out projects related to Green Human Resource Management, such as eco-friendly training and development courses. Green Human Resource Management seeks to support environmental responsibility and sustainability initiatives.

DOI: 10.22034/IJHCUM.2024.03.02

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
67	1	6

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

The food and beverage industry is one of the sectors that has a high demand during the COVID-19 pandemic because people need to consume nutritious food to increase their body's resistance to maintaining health (de Souza *et al.,* 2022) so the Ministry of Industry assessed the food and beverage industry as one of the manufacturing sectors that must be protected to continue to develop positively during the COVID-19 pandemic. The positive growth of the food and beverage industry sector is a momentum that must be maintained and increased so that it can consistently make a significant contribution to the national economy (Muslih, 2021; Stamopoulos *et al.,* 2024). It's been a challenging time for employees and employers, as the COVID-19 pandemic has impacted most organizations. During these difficult times, organizations need to establish strategies that keep people engaged and productive. However, it is the biggest challenge that relates to employee engagement sustainability in the workplace (Chen *et al.,* 2023; Jain *et al.,* 2024). Organizations must develop effective strategies to sustain their employees after being impacted financially, specifically in the Food and Beverage (F&B) industry. So, the F&B sector has struggled with sustainability in recent decades (Norizan *et al.,* 2022). The pandemic has caused the food and beverage industry to be negatively impacted since 2020 by the effects of the economic downturn. A significant number of workers, especially those with more experience, will quit, and companies risk losing their competitive advantage if they are reluctant to locate a replacement with equivalent qualifications. Over the past 20 years, many academic studies have focused on sustainability because it is an important long-term objective for organizations (Kavadis *et al.,* 2023) in all industries. However, in the modern era, the goal of employee engagement sustainability should be to positively impact "sustainable development by delivering simultaneously economic, social, and environmental benefits—the so-called triple bottom line (Pontecchiani, 2023). Long-term employee engagement is hard to establish and maintain without good Green Human Resources Management (GHRM) practices (Vahdati and Vahdati, 2018). Thus, it is proposed that by comprehending the breadth and depth of GHRM practices, organizations will be able to operate in a more ecologically responsible manner than they ever have before. Green Human Resource Management (Green HRM) is a contemporary management concept designed to impact employees' environmentally conscious behaviors, claim to Dixit (2022). Hence, Wisetsri *et al.,* (2023) highlighted that Green HR is the application of HRM techniques to enhance the practical utilization of assets within commercial organizations and, on a broader scale, advances the cause of environmental sustainability. Thus, sustaining employees in the Food and Beverage industry is critical to ensuring long-term business performance. The study aims to determine if Malaysian food and beverage companies can utilize factors that contribute to the long-term engagement of their employees. While retention is critical for success and creating a positive work culture, cultivating long-term employees will propel the company forward as their experience grows. This study can be used as a baseline for examining the impact of the Food and Beverage industry on employee sustainability as the industry grows and companies face numerous challenges as a result of COVID-19. To promote long-lasting employee engagement, companies can incorporate novel ecological methods that harness their workforce's talents and innovative approaches to tackling environmental performance concerns. This approach refers to promoting green human resources, and it helps organizations achieve confirmed sustainability (Chams and García-Blandón, 2019). Implementing green Human Resource Management can ensure the success of an organization's environmental performance, which plays an essential role in developing organizational sustainability (Pham *et al.,* 2020). Low morale, high turnover rates, and decreased productivity are all consequences of persistent low employee engagement that can have a detrimental financial impact on the business (Al-Suraihi *et al.,* 2021). The challenge of maintaining employee engagement and productivity while implementing green human resources management arises from the need for businesses to use environmentally friendly procedures (Pham *et al.,* 2020). According to Aggarwal *et al.* (2015), the researcher reviewed prior research and found that while some scholars have examined the significance of GHRM in the food and beverage industry, there is still a gap in this sector due to improper implementation of Green HRM practices and a lack of awareness among most employees. Since it explains how human resource

management policies work, the ability-motivation-opportunity theory and contingency theory is a key theoretical gap in green HRM that affects employee engagement sustainability at the organizational level (Yu *et al.,* 2020), which has shown that one of the best green human resources management strategies for ensuring the ongoing development of green management in most organizations is green training and development. This study filled a vacuum in the literature by reviewing sustainability-related aspects of employee engagement thoroughly and concentrating on recent research utilizing social exchange theory, social identity theory, and Gallup theory from a sustainability perspective. Prior analyses (Barney *et al.,* 2021; Nayak *et al.,* 2023) of organizational sustainability across various domains or industries mainly relied on theories such as resource dependency, social exchange, dynamic capability, resource-based view, and so forth. This is because employees and managers themselves are not aware of the benefits and best practices to achieve employee sustainability (Vanisri and Chandrapadhy, 2024). To summarize, sustainable employee engagement through Green Human Resource Management is a critical issue that organizations must address to achieve their sustainability goals while maintaining employee productivity and engagement. The study also offers insightful information on the significance of GHRM, which will be helpful for researchers, trainers, aspiring business owners, policymakers, and the government to take significant steps toward green Human Resource Management to sustain employee engagement. GHRM and sustainability business in the palm oil industry (Hendarjanti, 2022); GHRM and work employee engagement in the manufacturing industry (Stalin *et al.,* 2024); GHRM in driving green work engagement and green employee performance in the manufacturing industry (puspa Gustiah *et al.,* 2023); GHRM on employee green behavior and green work engagement in higher education (Aboramadan, 2022); and GHRM and green employee engagement in the automotive industry (Subburao *et al.,* 2023). As a result, the study has filled gaps in many industries. The body of knowledge determines Green Human Resource Management practices—green training and development, green recruitment and selection, or green compensation and rewards have the greatest influence and fill the gap in sustainability employee engagement in the Food & Beverage Industry among employees in Malaysia in 2023.

Literature review

In today's corporate environment, environmental management has gained more significance, as it is crucial for maintaining employee engagement and business sustainability. Many businesses have adopted the concept of GHRM in their HR departments. It is worth noting that some businesses in both developed and developing countries have integrated GHRM policies into their strategic plans. They strive to achieve sustainable long-term development. One of the key advantages of implementing GHRM in the food and beverages sector is the ability to heighten employee awareness, organizational innovation, and employees' innovation to sustainability and commitment to environmental management issues. In the context of organizational and employee perspectives, employee-driven innovation toward sustainability is an organizational change driven by ideas from employees in an organization. Changes that occur in the organization with new technological changes in the company, not only that, new skills in handling technology and thoughtful, creative ideas in the company's service because it encourages customers about a company's service. All types of innovation changes such as products, services, technologies, and markets will be considered employee-driven innovation (Tajpour *et al.,* 2018) toward sustainability if those who produce those products meet the criteria of who does and breaks paradigms and routines. HRM has an essential role within an innovation strategy, as it can, together with other areas, create, develop, and maintain actions that support and recognize innovative ideas and encourage employees to become actively engaged with the inclusion of innovation in their daily work lives (Azevedo *et al.,* 2021). Engagement in innovation has focused mainly on R&D (research and development)-based innovation, innovation created by experts, consumer innovation, and technology-based innovation (Kandampully *et al.,* 2023). There are many reasons why political, financial, and research institutions should devote more attention to the role of employee-driven innovation toward sustainability (Carlbäck *et al.,* 2023). Innovation toward sustainability can be conceptualized by comparing the concept with concepts related to non-R&D innovation (Lu *et al.,* 2024), non-technological innovation (Turci

et al., 2021), green HRM (Boominathan *et al.,* 2024), green transformation (Wang *et al.,* 2024), high-engagement innovation (McCool *et al.,* 2020), and direct participation in organizational change to sustain the organization's strategy and process (Bhat *et al.,* 2024; Opazo-Basáez *et al.,* 2024). Implementing good human resource management practices can enhance employee competence, innovation, and motivation leading to employee engagement sustainability. It has led to a positive impact on the financial performance of the company. GHRM involves incorporating environmental management principles into HRM activities, starting with recruitment and continuing through performance management, training and development, employee relations, compensation, rewards, and exits. A top building block of green human resource management is the ability-motivation-opportunity theory. This theory explains how policies related to human resource management can impact employee engagement and sustainability at the organizational level. A study by Yu *et al.,* (2020) found that implementing continuous green management and training programs is key for effective green human resource management in organizations. Employing green training and development techniques can be a means of fostering in employees a green mindset regarding the relevance of employee engagement sustainability (Moradeke *et al.,* 2021). Therefore, companies are beginning to recognize the value of green recruitment and selection. It is recommended that talent recruiters use a systematic, multidisciplinary approach to assessing talent (Larkin and O'Connor, 2017). Web-based recruiting provides recruiters with more information about their environmental practices than traditional channels such as brochures or newspaper ads (Renwick *et al.,* 2013). The study conducted by Masri and Jaaron (2017) found that implementing green recruitment and selection practices has a direct impact on sustainability. Previous research (Yong *et al.,* 2020) has shown a strong positive correlation between implementing GHRM practices and achieving favorable organizational and environmental outcomes. Employees demonstrating a commitment to eco-friendliness should be rewarded for environmental conservation efforts (Tulsi *et al.,* 2020). Organizations can implement many reward systems to improve employee motivation and learning skills, ultimately enhancing sustainability (Rahim *et al.,* 2018). These rewards not only show appreciation for workers but also incentivize participation in eco-friendly initiatives and practices. Presbitero (2017) discusses the need for literature to explore the relationship between human resource practices and employee engagement. Alnaqbi (2011) conducted a study to investigate the relationship between human resource practices and employee engagement. The study found no significant correlation between the two variables. Green HR practices have positive impacts on business, society, and the environment. Government agencies enforce green protection laws by recommending such practices. Organizations must adopt green HR practices to address environmental concerns and foster a responsive workforce through strategic planning.

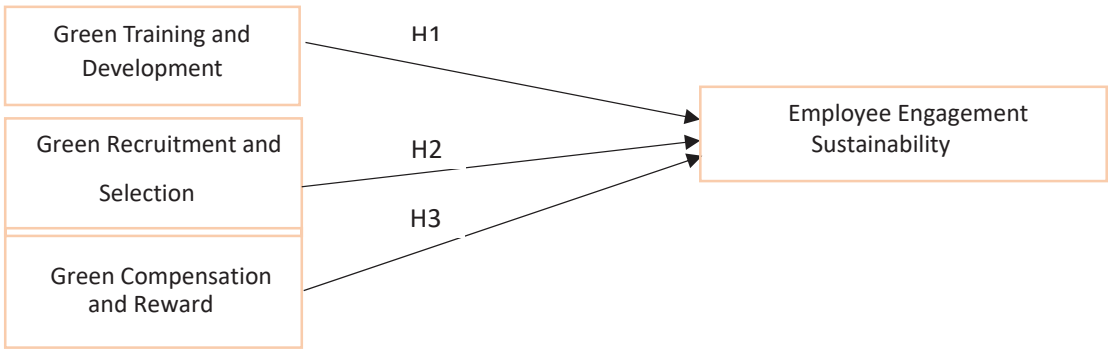
Hypothesis and theoretical foundation

Analytical framework

The following hypothesis is developed based on a review of the literature and the previous discussion on the conceptual model of the impact of GHRM and employee engagement sustainability. So hypothesis 1 supported the relationship between Green training and development and employee engagement sustainability in the Malaysian food and beverages Industry. A study (Alam *et al.,* 2023) claims that utilizing green training and development strategies can help cultivate in workers a green perspective on the importance of sustainability in employee engagement. Employee engagement is a crucial aspect of sustainable development, and various approaches can be considered to achieve this. Creating ad hoc strategies, policies, and processes is one way to promote sustainability in the workplace. It's essential to have a well-rounded approach that considers the needs of the employees and the organization. From the talent management viewpoint, companies provide employees with various opportunities to enhance their skills, knowledge, and expertise. These opportunities include training and development, recruitment and selection, compensation, and reward. It's a mutually beneficial exchange where the employees gain valuable experience while the company benefits from their improved performance (Raza *et al.,* 2023). For instance, GHRM practices, such as green training, can increase employees' knowledge and proficiency in sustainability, but this may not be sufficient to inspire employees to sustain

(Raza *et al.,* 2022). Hypothesis 2 indicates that green recruitment and selection is supported toward employee engagement sustainability in the Malaysian food and beverage industry. It is recommended that talent recruiters use a systematic, multidisciplinary approach to assessing talent (Larkin and O'Connor, 2017) because green recruitment and selection have a significant impact on employee work sustainability (Stalin *et al.,* 2024). Moreover, hypothesis 3 showed that green compensation and reward are positively correlated with employee engagement sustainability in the current study due to theories such as the Social Exchange Theory (SET), Social Identification Theory, and Gallup Theory framework would aid in comprehending how GHRM is linked to employee engagement sustainability (Ari *et al.,* 2020). It seems like (Rahim *et al.,* 2018) have identified different reward systems that organizations can utilize to enhance skill acquisition and encourage employees to work towards achieving sustainability goals. It's interesting how organizations can use incentives to motivate employees to contribute towards a common objective. It was inferred from Fig. 1 that Green Human Resources practices significantly impact employee engagement sustainability. The framework incorporates various theories and concepts, including green training and development, green recruitment and selection, and green compensation and reward. The framework highlights the crucial role of GHRM practices in promoting employee engagement sustainability. Fig. 1 illustrates how Green Human Resources practices affect employee engagement sustainability.

The Social-Exchange Theory (SET) framework is widely recognized as a prominent theory that elucidates the impact of green HR practices on sustainability outcomes related to employee engagement. This theory can be applied to comprehend the GHRM conceptual model. Organizations are constantly seeking a theoretical foundation for solutions; the social exchange theory plays a crucial role and aids in the theoretical perspective to address organizational conflicts (Kundi and Manipal, 2023). Suleman *et al.,* (2023) argued that implementing green HRM practices can reduce employee turnover rates, leading to increased employee retention rates and promoting sustainability. As illustrated in Fig. 1, GHRM indicators encompass green training and development, green recruitment and selection, and green compensation and reward. Having a proper GHRM (Green Human Resource Management) system in place is crucial because the successful implementation of environmental management systems requires effective human resource practices. As per the research conducted by Xie (2023) and Lau (2023), it has been identified that the integration of GHRM with environmental management systems can lead to better outcomes and sustainable business practices. According to the Social Identification theory, green human resource initiatives that improve employees' skills and motivation for work lead to positive performance outcomes (Karatepe and Karadas, 2012). Additionally, this approach can cultivate an environment where employees and the company engage in a mutually beneficial exchange of information, leading to increased employee engagement and motivation (Ahmeti, 2023). According to the Social Exchange Theory (SET), social interactions are focused on sharing resources, such as love, support, and material goods. The encouragement



Figs. 1: Conceptual model of the correlation between GHRM practices and employee engagement sustainability

of employee engagement sustainability may increase employees' willingness and capacity to act sustainably (Harrach *et al.,* 2020). This statement highlights the impact of organizational management on employee engagement sustainability. It suggests that the way organizations manage themselves and profit from them affects the level of employee engagement. The statement also implies that employee engagement is a two-way process that involves a benefit exchange between an employer and an employee. This idea is supported by Qadri and Bilal (2022). The Gallup model played an essential role in developing employee engagement, which has had a significant impact on the company's growth prospects. This impact encompasses aspects such as loyalty, high earnings per share, morale, open systems, financial well-being, brand image, favorable results, higher staff productivity, support for positive interpretation, essential change management, and sustainability (Shahzad *et al.,* 2023). Food and beverage businesses are increasingly mindful of employee engagement sustainability. And green management in today's cutthroat industry (Alyahya *et al.,* 2023).

MATERIALS AND METHODS

Survey design and data collection

The quantitative method has been employed in developing this study because participants could fill out the questionnaires at their own pace. The data collected from the respondents were analyzed by using a variety of tests and measures using IBM SPSS software version 26 (Karbassi and Pazoki, 2015). Inferential statistics were used as predictive methods to compare the study sample data to other samples or previous research to establish the validity of the variables. The study's assessment tools were chosen and designed with the study's goals. The study used content validity and construct validity as instruments for instrument creation and measurement. The operational definition of the study was used as the basis for construct validity, while the study's scope, objectives, and content determined the validity of the content. Given these considerations, the measurements used in this investigation are reliable. This study had little interference. This study is conducted in a non-contrived study setting, which means there will be no control over the degree of researcher intervention. This study applied a cross-sectional time horizon, in which information is primarily obtained at one time via a questionnaire to obtain measurable parameters associated with the dependent variable and independent variables (Doering *et al.,* 2020). This descriptive study explains how certain variables relate to one another (Loewenthal *et al.,* 2020). Deductive reasoning is employed in this study to test an established theory based on earlier research (Markovits et *al.,* 2018). Deductive reasoning is helpful when conducting quantitative research because it enables the creation of hypotheses based on previous studies and the execution of hypothesis tests using the collected data (Brisson and Markovits, 2020). After gathering data, a hypothesis test is carried out to evaluate the validity of the hypothesis using precise and accurate data (Anderson, 2000). According to the Annual Economic Statistic 2022 in the food and beverages industry by the Department of Statistics Malaysia (DOSM), the food and beverage industry employed in Klang Valley had 400,078 employees in 2023. The reason why this study is conducted in the food and beverages industry is due to its global relevance, economic significance, complexity, innovation, social impact, and career opportunities, the food and beverage industry presents a fascinating and multifaceted subject of study and can also help address its problems and shape its future. This particular study has made use of non-probability convenience sampling to gather data. For non-probability sampling, the sample size is determined using Taro Yamane's formula n = N/1 + Ne^2, where n represents the required sample size, while N represents the population size. For large populations, the researcher increased the sample size to 210 respondents to achieve a reliability level of 95% with an error rate of 0.05.

n = 400,078 / (1+400,078(0.05)2

n = 400,078 / (1+400,078(0.0025)

n = 400,078 / (1+1000)

n = 400,078 / 2000

n = 200

This study used self-administered online questionnaires, in which respondents will have access to a browser site to complete the survey at their convenience and uninterrupted. Both primary and secondary sources are used to gather data; primary sources with a social focus, such as focus groups and questionnaires, may be preferred; secondary sources can be found in publications, reports, and other sources. The general structure

Table 1: Result of the respondent's profile

Demography variables	n	%
Gender		
Male	98	46.7
Female	112	53.3
Race		
Malay	180	85.7
Indian	8	3.8
Chinese	18	8.6
Others	4	1.9
Age		
18 - 24 Years	24	11.4
25 - 34 Years	68	32.4
35 - 44 Years	82	39.0
45 - 54 Years	29	13.8
Above 55	7	3.3
Education		
Malaysia Certificate Level (SPM)	45	21.4
Diploma	55	26.2
Degree level	78	37.1
Master / PhD level	20	9.5
Others	12	5.7
Position in Organization		
Managerial Level	51	24.3
Executive Level	78	37.1
Non–Executive Level	69	32.9
Top Management	12	5.7
Experience in organization		
Less than 2 years	44	21.0
2 – 5 years	62	29.5
6 – 10 years	46	21.9
Above 10 years	58	27.6

of the questionnaire is straightforward and appealing, with a suitable introduction, clear guidelines, and a well-structured questionnaire. A questionnaire measurement method will be using a 5 Likert scale in this study. This method is used to reflect the compatibility between the items and responses. The value of (5) refers to the 'strongly agree' response level and the value of (4) refers to the 'agree' response level. Meanwhile, the value of 3 refers to a 'neutral' response level, a value of (2) a 'disagree' response level and a value of (1) a 'strongly disagree' response level. The questionnaire is divided into three sections Part A, B, and C. Questions in Part B, Part C, Part D, and Part E are related to green human resources management, which includes green training and development, green recruitment and selection, and green compensation and reward.

RESULTS AND DISCUSSION

Descriptive statistics and analysis for variables entering the analysis

A total of 210 survey questionnaires were returned by respondents, with a response rate of 100%. Table 1 shows that descriptive analysis results indicate that out of the respondents, 112 (53.3%) were female, while 98 (46.7%) were male. The frequency distribution and percentage of respondents based on gender are shown in Table 1. It can be concluded that there are more female respondents compared to male respondents, with a difference of 14 individuals. Table 1 analysis revealed that of the 180 respondents, 85.7 percent were of Malay ethnicity, followed by 18 (8.6%) Chinese, 8 (3.8%) Indian, and 4 (1.9%) other ethnic groups. In Malaysia, the majority of workers in the food and beverage sector are members of the Malay ethnic group. Regarding age distribution, the

Table 2: Result of the reliability and validity analysis

Indicator	No.of items	items	Cronbach Alpha	Factor Loading
Understanding of Green Human Resources Management	6	My employer's procedures Green HRM practices. Employees at my company are given green goals to work towards. My organization offers its staff members opportunities for green training and growth to encourage environmental ideals. My organization provides its staff with environmentally focused training to improve the knowledge and abilities needed for green management. My employer associates green workplace practices with benefits and income. In my organization, hiring and selection procedures are correlated with green workplace practices.	0.939	0.870
Green Training and Development	6	My company provides sufficient training to emphasize green management as a fundamental organizational value. My company takes into account an employee's eco-friendliness as part of their development assessment to sustain the employee in the organization. Employees gain a comprehensive understanding of the green human resources management policy during the training My company offers employees opportunities to receive training in environmental aspects. My company performs training needs analysis to determine the specific training needed for improvement of job satisfaction. The staff gets internet access to all training materials.	0.946	0.903
Green Recruitment and Selection	6	I believe the company incorporates Green Recruitment and Selection elements within its recruitment strategy. I believe the company takes into account candidates who displaying interest in and concern for environmental criteria I believe the company communicates its policies for environmental sustainability during the recruitment process. I am aware that the manager informed all employees that the company was seeking prospective candidates with environmental management competencies. I am aware that to retain personnel, the company uses environmentally friendly recruitment and selection procedures. In my opinion, the organization considers how environmental management and personal identity mesh during the hiring and selection process.	0.945	0.916
Green Compensation and Reward	6	I am aware that the company practices Green compensation and rewards. My company offers incentives (such as stock options, additional leave days, coupons, etc.) to employees for	0.901	0.836

Continued Table 2: Result of the reliability and validity analysis

Indicator	No.of items	items	Cronbach Alpha	Factor Loading
		participating in sustaining and engaging employees in eco-friendly practices activities within the organization. Employees are rewarded financially for their performance. Incorporating environmentally-conscious compensation and rewards systems will result in long-lasting employee engagement Engaging in green compensation and rewards practices motivate me to remain with the organization. Green compensation and rewards can enhance a company's efforts to implement sustainable practices.		
Employee Engagement Sustainability	6	My company motivates me to go beyond what I would do in a similar role elsewhere. Employee engagement sustainability is a significant factor for me when choosing which company to work for. I am aware of an employee engagement policy on sustainability. Employee engagement sustainability is key to engaging the workforce of the future. I am satisfied with the opportunities available in the company to utilize my skills and talents. I am satisfied with the company's stance on sustainability, based on the effectiveness of its engagement process.	0.928	0.893

study's findings indicate that 82 respondents (39%) within the 35 -44 years old, followed by 68 (32.4%) within the 25-34 years age range, followed by 45-54 years old, 18-24 years old were 24 (11.4%), and another 7 respondents (3.3%). It can be observed that most respondents within 35-44 years old. Meanwhile, 62 respondents (29.5%) have been working within 2-5 years in the food and beverages industry in Malaysia, 58 (27.6%) respondents working for more than 10 years in the organization, followed by 46 (21.9%) respondents have been working within 6-10 years and 44 (21%) respondents less than two years working in the organization. According to Table 1, the majority of respondents were at the executive level, with 37.1% of them holding this position. Non-executive level employees made up 32.9% of the respondents, while 24.3% were at the management level, and only 5.7% were in the Top Management category. The high number of executives may be due to the degree level education requirement for this position, which is also reflected in the education level results.

Reliability and validity analysis

The validity and reliability of an instrument are crucial to maintaining the accuracy of the instrument and preventing it from being exposed to errors (Cheraghipoor *et al.,* 2024). The higher the validity and reliability of an instrument, the more accurate the data obtained, resulting in a good and high-quality study (Samimi and Nouri, 2023). The following are the Cronbach's Alpha values for this research instrument as shown in Table 2. The closer the value of Cronbach's Alpha is to 1, the higher the reliability level (Bougie *et al.,* 2019). While the reliability value for Cronbach's Alpha greater than 0.3 is considered good, greater than 0.5 is better, and greater than 0.7 is strong (Shrestha, 2021). Overall, this research

Table 3: Normality Test (Skewness and Kurtosis)

	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
B_Understanding_HRM	-.511	.168	.238	.334
C_Green_Traning_Development	-.605	.168	.448	.334
D_Recruitmen_N_Selection	-.395	.168	.013	.334
E_Compensation_N_Reward	-.786	.168	1.448	.334
F_Employee_Engagement_Sustainability	-.567	.168	1.034	.334

Table 4: Correlation analysis

---The definition??	GTD	GRS	GCR	EES
Green training development	1	.873**	.822**	.760**
Green recruitment and selection	.873**	1	.856**	.743**
Green compensation and reward	.822**	.856**	1	.762**
Employee engagement sustainability	.760**	.743**	.762**	1

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

Table 5: ANOVA Test

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	77.763	3	25.921	121.127	.000[b]
	Residual	44.084	206	.214		
	Total	121.847	209			

instrument has a high level of reliability, i.e., $\alpha = 0.95$.

Normality Test

Table 3 demonstrates how the study used skewness and kurtosis to evaluate the data's normalcy. Skewness and kurtosis in a normal distribution are predicted to be 0. Values of kurtosis and skewness between -1 and +1 are regarded as acceptable. The computed skewness and kurtosis values, as displayed in Table 3, are within this typical range, suggesting that the data is appropriate for additional examination.

Correlation Analysis

Davis (1971) defined a strong correlation as having a correlation coefficient of 0.70 or higher and a good correlation range of 0.50-0.69. Table 4 presents the study's findings, which show a strong correlation between employee engagement and sustainability and green HRM practices (recruitment and selection, training and development, and compensation and reward). In particular, the results show that green recruitment and selection and employee engagement and sustainability are significantly correlated ($r = 0.743$, $p \leq 0.01$) and that there is a significant and high relationship between green training and development and employee engagement sustainability ($r = 0.760$, $p \leq 0.01$). In addition, there is a noteworthy and robust correlation between green compensation and reward and employee engagement sustainability ($r = 0.762$, $p \leq 0.01$). The study finds that there are strong and significant correlations between the following GHRM practices: Green Recruitment and Selection and Green Training and Development ($r = 0.856$, $p \leq 0.01$), Green Training and Development, and Green Compensation and Reward ($r = 0.822$, $p \leq 0.01$), and Green Training and Development and Green Training and Development ($r = 0.873$, $p \leq 0.01$). The positive correlation between the variables indicates their strength and direction.

Multiple regression analysis

It is evident from Table 5 that the combination of these three independent variables has a noteworthy effect on the sustainability of employee engagement. The findings show that the independent variables collectively explain 63.3% of the variation in employee engagement sustainability that has been observed. This regression is significant, as seen in the table below [$F (206=121.12$, $P<0.05$).

The findings are presented in Table 6, the results of

Table 6: Summary of discussion findings

Hypothesis	Decision	Results
H_1: Green training and development and employee engagement sustainability are correlated.	Positive (p-values= .000)	Hypothesis Accepted
H_2: Green hiring and selection practices and sustainable employee engagement are correlated.	Positive (p-values= .236)	Hypothesis Accepted
H_3: Green compensation and reward and employee engagement Sustainability are correlated.	Positive (p-values= .000)	Hypothesis Accepted

the study analysis indicate that all three variables have a positive relationship, and all of them are significant. It aligns with earlier research findings (Abualigah *et al.,* 2023), which substantiate the positive correlation between GHRM and green creativity.

The hypothesis analysis for the study is presented in Table 6. Among the three variables, Green Compensation and Reward have the highest impact on the sustainability of employee engagement. Based on the findings of H1, there is a significant relationship between Green Training and Development and employee engagement sustainability in the Malaysian food and beverage industry with a significant p-value of .000. There is a positive correlation between Green Training and Development and Employee Engagement Sustainability ($r = 0.760$, $p \leq 0.01$). Moreover, this discovery is in line with the Social Identity Theory (SIT), which posits that employees who identify with a "green" organization (made possible by GHRM) are more inclined to support and participate in environmental initiatives within that organization. Offering green training can improve employees' skills and knowledge (skill-enhancing), promote employee engagement in sustainable initiatives (opportunity-enhancing), and link employee rewards and compensation to green behaviors (motivation-enhancing) are likely to encourage employees to generate innovative and valuable green ideas and solutions to achieve environmental objectives. Farooq *et al.,* (2021) suggest that incorporating green training, restructuring performance evaluations, rewards, compensation, and promotion criteria around employees' eco-friendly behavior can improve the Food and Beverage Industry's green innovation. The findings also indicate a positive correlation between Green recruitment and selection and employee engagement sustainability in the Malaysian food & beverages industry, with significant p-values of .236 for hypothesis 2. According to correlation analysis, there is a significant correlation between Green Recruitment and Selection (GRS) and employee engagement sustainability. The correlation coefficient (r) is 0.743, with a p-value of ≤ 0.01. The social exchange theory is used to examine GRS. This theory focuses on the relationships and interactions between individuals and organizations. In the context of GRS, the social exchange theory helps to explain the dynamics between organizations and potential employees concerning environmental responsibility and sustainability. Aligning green recruitment and selection practices with environmental responsibility and sustainability can lead to positive perceptions, trust, and commitment from candidates. Ultimately, this contributes to the success of the organization. There is a strong relationship ($r = 0.762$, $p \leq 0.01$) between green compensation and reward, employee engagement, and sustainability (H3). Compensation and rewards that promote environmentally friendly practices are crucial in fostering sustainable employee engagement. They not only incentivize employees but also align their values with those of the organization, creating a culture of sustainability. It leads to increased participation in sustainability initiatives, resulting in positive environmental and sustainability outcomes for the organization.

Practical and theoretical implication

GHRM empowers managers to shape employees' perspectives on sustainability, foster support for environmental quality, and enhance organizational performance. Organizational management places a heightened focus on GHRM functions, particularly within the realm of green human resource recruitment and selection. This emphasis aims to enhance the social and environmental performance of the organization by aligning recruitment and selection processes with the strategic green objectives of the organization. This approach ensures the hiring of

employees who possess green values and behaviors. Organizations that embed sustainability capabilities are also more likely to develop monitoring capabilities to support the development of sustainable products and processes. As noted by Adams *et al.,* (2023), organizations in the food and beverage industry are more likely to realign their strategies toward social responsibility. Therefore, management should prioritize monitoring capabilities that enable them to seize opportunities in both the external and internal environments, thus advancing their corporate social performance from a sustainability perspective in a developing country context. From a broader perspective, the study's findings support corporations in addressing the extensive Sustainable Development Goals agenda, particularly regarding sustainable consumption and production through the adoption of GHRM practices. Additionally, the study underscores the importance of developing sustainability-oriented capabilities in various industries, including textiles, pharmaceuticals, manufacturing, chemicals, and automobiles. It aligns with Malaysia's environmental policy objectives, aimed at conserving the country's environment and enhancing the overall quality of life. As a result, this study is significant because it provides a valuable framework for understanding the dynamics of organizational sustainability. It recommends management make hiring environmentally conscious workers and acquiring monitoring capabilities top priorities for a corporate strategy to meet social equality and environmental conservation goals.

Limitations and future research

It is essential to recognize the limitations of this study, which only focuses on the food and beverages sector in Malaysia. Future research could involve comparing sustainable performance across different service sectors and industries, not just food and beverages. Additionally, the constructs could be measured as higher-order variables in subsequent studies. There are limitations in this study, such as the sample size of respondents, the methods used, and the demographics selected by the researcher in the study are limited. Like the study conducted by the researcher, its limitations are confined to only a few indicators in Green Human Resources. The second limitation is that the study was conducted using quantitative methods. Third, the sample of respondents was drawn from F&B industry employees in the following locations: (a) Kuala Lumpur and (b) Selangor. As a result, people working in different places may have varied experiences. Fourth, the study did not specifically categorize the employees' skills of working in the F&B industry. It would be beneficial to adopt a comprehensive GHRM bundle approach in the future study that includes all GHRM practices to evaluate their impact on employee engagement sustainability.

CONCLUSION

This study emphasizes the influential role of a company in developing ethical HR practices. It proposes the adoption of GHRM as a long-term managerial framework that prioritizes talent retention and motivation and aligns the organization's strategy with economic, social, and environmental considerations. Implementing sustainable GHRM practices in the food and beverage industry can have a positive impact. Organizational culture benefits from employee engagement through job security, work-life balance, and self-responsibility. It is crucial to carry out additional research on green HR initiatives in the Malaysian food and beverages industry. It will enable all organizations to implement the practices of GHRM effectively. It will require presenting the information in a way that is easily understandable by Human Resource Officers who play a critical role in the organization's operations. Additionally, the development of an evolved GHRM framework model can be considered as a vehicle for a more holistic evaluation of employee engagement sustainability. Sustainability employee engagement and GHRM may contribute to the development of an effective organizational culture, job security, health promotion, flexibility, participative leadership, a value-added economy, self-responsibility, and work-life balance. Furthermore, GHRM empowers managers to shape employees' perspectives on sustainability, foster support for environmental quality, and enhance organizational performance. The Pembangunan Sumber Manusia Berhad (PSMB) Act 2001, which may be in place in some countries, is commonly referred to as the Human Resources Development (HRD) Corporation and is associated with the Green Human Resources Management (GHRM) strategy. A legal framework known as the PSMB Act 2001 controls the creation and management of a fund intended to assist in the advancement of human resources within

a particular jurisdiction. The Government of Malaysia required the extension of the PSMB Act 2001 with effect from March 2021 in its 11th Malaysia Plan (11MP), which falls under Strategic Thrust 5 - Focus Area C: Strengthening Lifelong Learning for Skills Enhancements. It involves opening up HRD Corp's resources, initiatives, and services to all sectors of the economy. The fund gathered under the PSMB Act 2001 was used to provide training, education, and skill development programs for the employees. The connection between Green Human Resource Management (GHRM) and the PSMB Act 2001 can vary depending on the specific policies and regulations of a given country or region. Organizations can use funds from HRD Corps to implement environmentally friendly training and development programs that align with the sustainability and environmental responsibility objectives promoted by GHRM. It is important to note that the relationship between GHRM and PSMB Act 2001 would be subject to the legal and regulatory framework of the specific jurisdiction in which an organization operates.

AUTHOR CONTRIBUTIONS

N. Razali performed the literature review, experimental design, analyzed, and interpreted the data, and H. Vasudevan prepared the manuscript text and manuscript edition. N. Razali and H. Vasudevan performed the experiments and literature review, compiled the data, and manuscript preparation. N. Razali and H. Vasudevan performed and compiled the data analysis and findings for the manuscript edition.

ACKNOWLEDGEMENT

The author would like to grab this opportunity to express our gratitude and deep thankfulness for encouraging us to accomplish this kind of research study that shares the author's opinion and recommendation when pursuing their research work.

ABBREVIATIONS

AVE	Average Variance Extracted
EES	Employee Engagement Sustainability
GHRM	Green Human Resource Management
GTD	Green Training and Development
GRS	Green Recruitment and Selection
GCR	Green Compensation and Rewards
HP	Hypothesis
p-value	Probability value
R^2_{adj}	Adjusted coefficient of determination
R^2	Coefficient of determination
r	Pearson correlation coefficient
r-value	Pearson correlation coefficient
$\overline{Y}$	Average of observed data
$\propto$	Level of significance

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HOW TO CITE THIS ARTICLE

Razali, N.; Vasudevan, H., (2024). The impact of implementing green human resources practices on employee engagement sustainability. Int. J. Hum. Capital Urban Manage., 9(3): 389-404.

DOI: 10.22034/IJHCUM.2024.03.02

URL: https://www.ijhcum.net/article_709463.html

Int. J. Hum. Capital Urban Manage., 9(3): 405-412, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Angle optimization of home solar panels for urban energy management

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ARTICLE INFO

Article History:
Received 15 December 2023
Revised 10 February 2024
Accepted 13 March 2024

Keywords:
Atmospheric length
Solar panel
Optimum angle
Zenith angle

ABSTRACT

BACKGROUND AND OBJECTIVES: Solar panels are always installed at an angle in which receive the maximum amount of energy. Small and even 1-degree changes in the angle of the installed panel have a significant impact on the annual energy received. The objective of this study was to study the evaluation of change in the sun's radiant energy on the surface perpendicular to the radiation during the day.

METHODS: Calculations of changes in the intensity of radiation on the surface of the panel are generally performed by assuming that the intensity of solar radiation is constant on the surface perpendicular to the radiation during the day (choosing the solar constant) and multiplying it by the cosine of the azimuth angle (which varies during the day). Since the sun's rays travel different lengths in the atmosphere at different times of the day, the intensity of the sun's radiation on the surface perpendicular to the radiation varies throughout the day. In this study, the effect of daily changes in the intensity of solar radiation on the surface perpendicular to the radiation, on the optimal angle of the solar panel has been investigated.

FINDINGS: The results showed that the daily optimal angle difference reported in this study compared to previous studies is more than 5 degrees in some cases. Also, installing the panel under the optimal daily angle (for day number 100) and the correct yearly angle resulted in receiving 128.56 kilowatts per square meter and 2.977 megawatts per square meter more energy, respectively.

CONCLUSION: According to the results of this research, the annual optimal angle for a geographic latitude of 30 degrees, taking into account the changes in solar radiation energy on the surface perpendicular to the radiation, is 26 degrees, which is 4 degrees different from the geographic latitude. Also, the results show that if the panel is installed at an angle of 30 degrees, the energy received annually is 16.122 megawatts per square meter less than if the panel is installed at an angle of 26 degrees.

DOI: 10.22034/IJHCUM.2024.03.03

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
34	4	4

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

The increasing population of cities has caused an increase in environmental pollution (Ehzari *et al.,* 2022; Samimi, 2024; Samimi *et al.,* 2023a) and a significant increase in energy consumption for domestic use (Samimi and Nouri, 2023; Cheraghipoor *et al.,* 2024; Samimi *et al.,* 2023b). Environmental pollution can be solved to some extent by physicochemical (Mohadesi *et al.,* 2024; Samimi and Safari, 2022; Sarmurzina *et al.,* 2023), and biological (Samimi *et al.,* 2021; Samimi and Shahriari-Moghadam, 2023; Samimi and Mansouri, 2024) methods, but the best way is to prevent the factors that cause urban pollution (Sulistyowati *et al.,* 2023; Seethong *et al.,* 2023; Mardianti and Purba, 2023). Air pollution in cities is one of the most important causes of excessive energy consumption (Salvaraji *et al.,* 2023; Ernyasih *et al.,* 2023). Supplying part of the energy needed by cities using renewable energy is one of the solutions for sustainable urban development (Ramli *et al.,* 2022; Bogachov *et al.,* 2022). Solar energy is one of the most important forms of renewable energy available in many areas compared to other types, even wind energy (Abrofarakh and Moghadam, 2024; Samimi and Moghadam, 2024a). Fresh water production using solar still devices (Moghadam and Samimi, 2022) or desalination of reverse osmosis units is one of the applications of using solar energy (Bdour, *et al.,* 2023; Samimi and Moghadam, 2024b). One of the methods of using solar energy is to convert it into electrical energy using the photovoltaic phenomenon (Kabir *et al.,* 2023; Fares *et al.,* 2022). Solar panels are tools that use this mechanism (photovoltaic phenomenon) to convert the radiant sun energy into electrical energy (Abdallat *et al.,* 2024). This technology has developed adequately in recent years; so extensive studies are being done to reduce the cost and increase the conversion efficiency. The efficiency rate of commercial panels available in the market is about 25 percent (%) and the average cost of solar electricity is about 3-6 cents per kilowatt–hour. Typically, photovoltaic panels to receive solar energy are installed on the roofs of houses, where they receive the most solar radiation. The panels must be equipped with a solar tracking system to get the most solar energy possible. Due to the high cost of these systems as well as requiring specialized maintenance, they are often not used for economic reasons. The panels installed permanently should be placed under an optimal angle to receive the maximum radiant energy from the sun throughout the year. So far, many studies have been conducted on optimizing the installation angle of solar panels and almost similar results have been reported (Despotovic and Nedic, 2015; Alqaed *et al.,* 2023; Gupta *et al.,* 2023). The studies show that the latitude of the installation location affects the annual optimal angle. Results of different studies in different places converge on the approximate similarity of the optimal angle and the latitude of the panel installation location. This means that although different studies may have suggested different values for the optimal angle, in most cases, the suggested value was in the latitude range of the place of investigation. In addition to the annual optimum angle, studies have also been conducted on the semi-annual, seasonal, monthly, and daily optimum angle. In some of these studies, results different from previous studies have been presented. For example, Moghadam *et al.* (2015) showed in their study that although in the northern hemisphere, the solar panel should be installed in the east-west direction and towards the south, on some days of the year, the optimal angle is towards the north. However, it is difficult to adjust the panel's angle every day under the optimal angle. Therefore, it is suggested that this work be done monthly, quarterly, or semi-annually. Determining the daily energy intake is the first step in calculating the annual energy intake. For this purpose, the changes in the intensity of the sun's radiation from the beginning to the end of a certain day are calculated. The energy received is calculated by integrating these changes in terms of time during the day. The literature review shows that the changes in the intensity of the sun's radiation in terms of time during the day were calculated in many studies using the product of the solar constant in the cosine of the zenith angle (Njoku *et al.,* 2023; Bailek *et al.,* 2018). In other words, the intensity of the sun's radiation during a certain day is considered constant. This is even though the intensity of the sun's radiation changes during the day (because it travels a different length in the atmosphere) and must be investigated. Small changes in the annual optimal angle will cause significant changes in the received energy throughout the year. Therefore, accurate determination of this angle is of great importance. This study aimed to determine the optimal angle of solar collectors by considering the changes in the intensity of the sun's

radiation during the day. The current work has been performed in Zahedan, Iran in 2024.

MATERIALS AND METHODS

The intensity of solar energy radiation on the surface perpendicular to the sun's rays, outside the earth's atmosphere in one day, is constant which is known as the solar constant. This value changes on different days due to the change in the distance between the Earth and the sun, but these changes are less than 2%. However, the intensity of the sun's radiation on a surface perpendicular to the sun's rays on the earth (sea level) is completely variable during the day. A part of the sun's radiant energy is absorbed or scattered by hitting the particles in the atmosphere. According to Fig. 1, the sun's rays travel a much longer path in the atmosphere at sunrise to reach the earth's surface. Meanwhile, at noon, the sun's rays will travel the least possible path in the atmosphere on a given day. Therefore, during the day, the lowest radiation energy on the surface perpendicular to the radiation rays will be at sunrise and sunset, and the highest amount will be at noon.

RESULTS AND DISCUSSION

Intensity of the sun's radiation on a surface perpendicular to the radiation versus the zenith angle

According to Fig. 1, it is clear that the length of the sun's rays in the atmosphere depends on the sun's zenith angle. Table 1 presents the changes in the sun's radiation energy on the surface perpendicular to the radiation on the earth's surface (sea level) in terms of the sun's zenith angle. Fig. 2 shows the results of fitting the values of Table 1 with Eq. 1 (Moghadam *et al.,* 2011).

Table 2 shows the constants of Eq. 1 and the R, coefficient of determination (R^2), and adjusted R-squared (R_{adj}) values. Fig. 3 shows the changes in solar radiation energy on the surface perpendicular to the radiation in several days for a latitude of 30 degrees. As it is clear from Fig. 3, at the beginning and end of the day, the intensity of the sun's radiation is

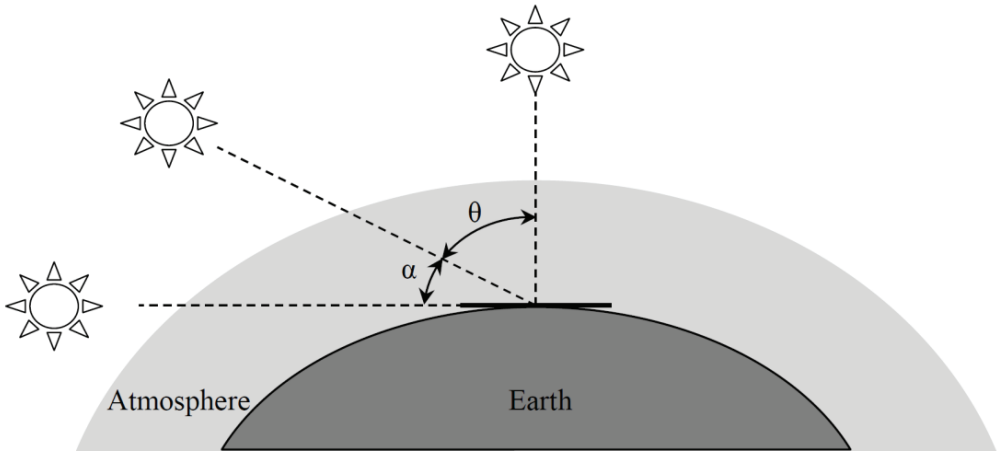
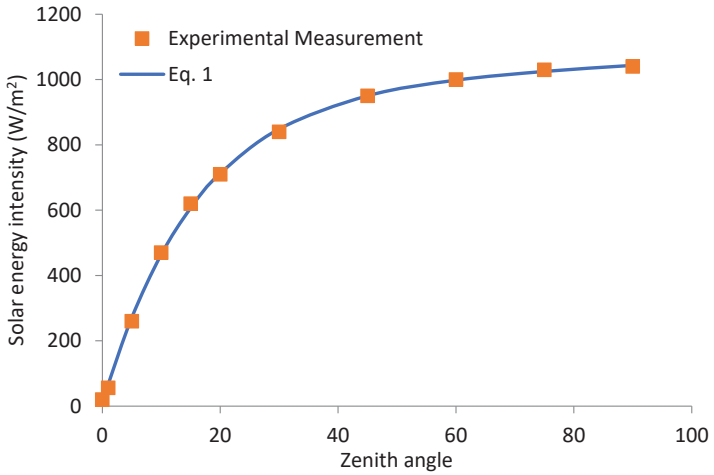


Fig. 1: Changes in the length of the sun's rays in the atmosphere at different times of the day

Table 1: The sun's radiant energy on the surface perpendicular to the radiation on the earth's surface versus the zenith angle

Zenith angle	Solar energy intensity (kW/m^2)
90	1040
75	1030
60	1000
45	950
30	840
20	710
15	620
10	470
5	260
1	56
0	20



9Fig. 2: Comparison between the experimental values of changes in solar energy intensity at different zenith angles and the values obtained from Eq. 1

Table 2: Parameters of Eq. 1, and acceptability of fitting experimental data

Parameter of Eq. 1	Value
a	968.4
b	0.0008678
c	-961
d	-0.06298
Goodness of fit	**Value**
SSE	711.4
R-square	0.9995
Adjusted R-square	0.9993
RMSE	10.08

much lower than at other times during the day.

$$I = a \times exp(b \times \theta) + c \times exp(d \times \theta) \quad (1)$$

Where I is the intensity of the sun's radiation on the surface perpendicular to the radiation on the earth's surface (sea level) and θ is the sun's zenith angle. The constants of Eq. 1 and the fitting parameters are presented in Table 2.

The influence of variable daily sunlight intensity on the optimal angle

To find the optimal angle of solar panels during the day, the amount of energy received by the panel at different angles is calculated, and then the angle under which the most energy is received is introduced as the optimal angle. The same process is used to determine the optimal monthly, seasonal, semi-annual, and annual angles. The amount of energy received daily by the panel at a certain angle is obtained from the integral result of the energy changes received during the day versus time. In previous studies, the changes in the energy received by the panel at a certain angle have been related only to the changes in the radiation angle on the panel. In this way, the received solar energy is obtained by multiplying the solar constant by the cosine of the radiation angle on the panel. Variations of the radiation angle on a panel installed at an angle β concerning the horizon surface are obtained using Eq. 2 (Moghadam *et al.,* 2011).

$$\text{Cos } \theta = \cos(\phi-\beta)*\cos(\delta)*\cos(\omega)+\sin(\delta)*\sin(\phi-\beta) \quad (2)$$

Where θ is the angle of the summit side, ϕ is the latitude, β is the installation angle of the panel relative to the horizon, δ is the deviation angle, and ω is the hour angle. The deviation and hour angles

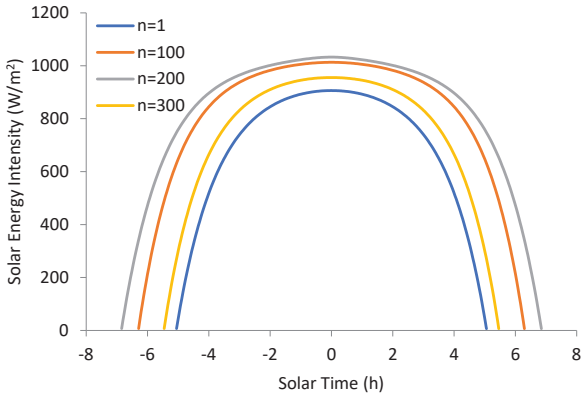


Fig. 3: Solar radiant energy on the surface perpendicular to the radiation versus time on several different days for a latitude of 30 degrees

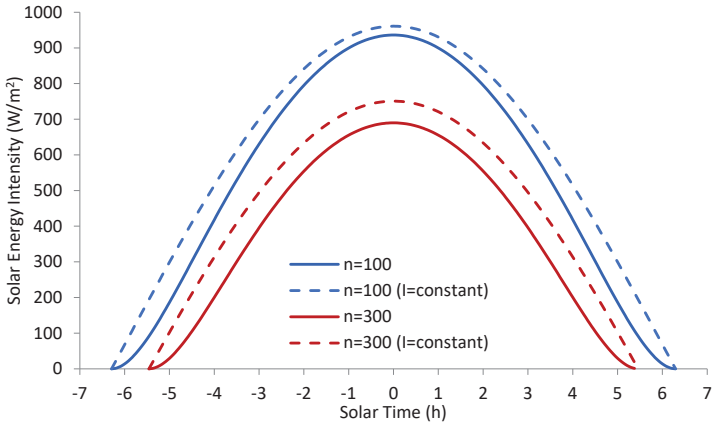


Fig. 4: The sun's radiant energy on the surface of the horizon considering variable daily radiation intensity (solid lines) compared to constant daily radiation intensity (dashed line)

are calculated using Eqs. 3 and 4, respectively (Moghadam *et al.,* 2011).

$$\delta = 23.45\sin[360(284 +) / 365] \quad (3)$$

$$\omega = \pm (360/24)t \quad (4)$$

While the radiation angle varies during the day, the intensity of the sun's radiation (as shown in Fig. 3) also varies during the day. Fig. 4 shows the changes in the sun's radiant energy on the horizontal surface, considering the variable daily radiation intensity compared to the fixed daily radiation intensity, for two different days. As it is clear from the figure, taking into account the changes in radiation intensity during the day, the amount of energy received by the panel at the beginning and end of the day is less compared to the case of constant radiation intensity during the day. As a result, these moments of the day are less important in finding the optimal angle. Table 3 shows the amount of energy received by the panel for a specific day of the year at different installation angles in two modes of fixed and variable daily radiant energy. According to the values in Table 3, it can be seen that considering the change of radiant energy during the day, the optimal angle is -4, while in the case of constant radiant energy, the optimal angle is -9. The results show that if the correct optimal angle of -4 degrees is used, 128.56 kilowatts per square meter (kW/m^2) more energy is received during the day.

Table 4 shows the amount of energy received annually by the panel in two modes fixed and variable daily radiant energy. According to the values in Table 4, it can be seen that taking into account the variation of radiant energy during the day, the annual optimum angle for the panel installed at 30 degrees latitude is 26 degrees, while in the case of non-constant radiant energy, the optimal annual angle is 28 degrees. The

Table 3: Energy received by the panel at different angles for day number 100

β		-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
Received energy ($\times 10^6$ W)	Variable daily radiation	29.38422	29.40329	29.41339	29.41454	29.40673	29.38996	29.36424	29.32958	29.28598	29.23346
	Constant daily radiation	42.67506	42.77057	42.85305	42.92248	42.97884	43.0221	43.05226	43.06931	43.07323	43.06404

Table 4: Energy received by the panel at different angles for the whole year

β		30	29	28	27	26	25
Received energy ($\times 10^9$ W)	Variable daily radiation	8.523858	8.531706	8.537011	8.539772	8.539988	8.537658
	Constant daily radiation	13.08101	13.08516	13.0855	13.08202	13.07475	13.06367

results show that if the optimal angle of 26 degrees is used, 2.977 megawatts per square meter (MW/m^2) more energy will be received throughout the year.

CONCLUSION

Accurately determining the optimal angle of solar panels is the subject of many studies. In this study, the effect of daily changes in the intensity of solar radiation on the surface perpendicular to the radiation, on the optimal angle of the solar panel has been investigated. For this purpose, firstly, the experimental data of the changes in the intensity of the sun's radiation on the surface perpendicular to the rays of radiation on the earth (sea level) in terms of the azimuth angle were well fitted by a mathematical relationship. In this regard, the azimuth angle was the independent variable and the radiation intensity on the perpendicular surface was the dependent variable. Then, using this relationship, the changes in the sun's daily radiant energy were obtained on a panel installed at a certain angle. The total amount of energy received daily was calculated by integrating the radiant energy changes versus time during the day. The optimal daily angle was obtained from the comparison of the total daily received energy by the panel at different angles. The results showed that since at the beginning and end of the day, the intensity of the sun's radiant energy is lower than at other times of the day, these moments have less effect on the optimal angle. Also, the optimal angle obtained by taking into account the changes of the sun's radiant energy on the vertical surface during the day compared to keeping this value constant was more than 5 degrees in some cases. The optimal angle obtained from this research for day No. 100 at 30 degrees latitude was about -4 degrees, while previous studies wrongly suggested the optimal angle to be -9 degrees. The results showed that using the correct optimal angle of 128.56 kW/m^2 more energy to be received. Also, the annual optimal angle obtained from this research for the latitude of 30 degrees is 26 degrees, if the daily radiation intensity is considered constant on the surface perpendicular to the radiation, the optimal angle is mistakenly obtained as 28 degrees. The results showed that if the optimal angle of 26 degrees is used, 2.977 MW/m^2 more energy will be received by the solar panel per year.

AUTHOR CONTRIBUTIONS

M. Moghadam conducted the literature review, analysis and wrote the original draft. J. Nouri edited the manuscript. The corresponding author, M. Samimi, managed the project, performed the validation tests, and reviewed the manuscript.

ACKNOWLEDGEMENT

The authors would like to acknowledge Kermanshah University of Technology, University of Sistan, and Baluchestan and all who supported this study.

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.

ABBREVIATION

%	Percent
α	Altitude (elevation) angle
β	Tilt angle of solar panel
δ	Declination angle
ϑ	Zenith angle
φ	Latitude
ω	Hour angle
h	Hour
I	Solar energy intensity perpendicular to sun's rays
kW/m^2	Kilowatt per square meter
MW/m^2	Megawatt per square meter
n	Day number of the year
$RMSE$	Root Mean Squared Error
R^2	Coefficient of determination
R_{adj}	Adjusted R-squared
SSE	Sum of Squares of Errors
t	Time distance to solar noon (in h)

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HOW TO CITE THIS ARTICLE

Moghadam, H.; Nouri, J.; Samimi, M., (2024). Angle optimization of home solar panels for urban energy management. Int. J. Hum. Capital Urban Manage., 9(3): 405-412.

DOI: 10.22034/IJHCUM.2024.03.03

URL: https://www.ijhcum.net/article_711943.html

Int. J. Hum. Capital Urban Manage., 9(3): 413-428, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Urban management and sustainable business by entrepreneurs

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ARTICLE INFO

Article History:
Received 18 November 2023
Revised 16 January 2024
Accepted 08 March 2024

Keywords:
Entrepreneurs
Factor analysis
Mixed-method approach
Regression analysis
Sustainable urban practices

ABSTRACT

BACKGROUND AND OBJECTIVES: *The nation's urban sector has experienced significant changes since industrialization, both in terms of growth and improvement in terms of creating jobs and the depletion of natural resources. The development and destruction are commendable and need mention and attention. These days, issues such as environmental degradation, the wealth gap, and unequal access to opportunities and resources are increasing. These concerns have increased the need for urban management through sustainable and planned development. The development cannot be sustained unless the depletion is controlled and taken care of. The current study focused on how urban regions have changed and how sustainable development helps cope with the changes. Furthermore, the study focused on enhancing the well-being of urban communities and promoting inclusivity to develop sustainable businesses that are economically sustainable in the long run. The novelty of the study is that explores how sustainable development can mitigate the impacts of urban change and enhance community well-being and inclusivity.

METHODS: *Quantitative methodologies, such as surveys and statistical analyses, may have shed light on the broader impact of sustainable business practices on urban development. To complement these findings, qualitative case studies and interviews could have fostered deeper insights into specific initiatives and the perspectives of entrepreneurs navigating this landscape. A mixed-methods approach, weaving together quantitative trends with rich qualitative narratives, would have further enriched the understanding of motivations and challenges encountered. Ultimately, regardless of the specific methodologies employed, this research likely aimed to achieve a holistic understanding of the intricate connections between urban management, sustainable business practices, and the innovative spirit of entrepreneurs driving change in India. In this study, the researcher used regression analysis and factor analysis to achieve the research objectives.

FINDINGS: The entrepreneurs examined in the study exhibited a proactive stance towards critical aspects of sustainable business, notably waste management, energy efficiency, and resource optimization. The study identifies significant associations between key variables and sustainable urban development. Urban management demonstrates a positive impact (B = 1.286, SE = 0.621, Beta = 0.116, T = 2.071, P = 0.0039), highlighting its crucial role in shaping sustainable practices. Sustainable practices, in turn, exhibit a strong positive correlation (B = 1.088, SE = 0.257, Beta = 0.238, T = 4.242, P = 0.0001), indicating their pivotal role in driving urban development towards sustainability. These findings underscore the importance of integrating effective urban management strategies and sustainable practices to foster inclusive and resilient urban communities.

CONCLUSION: The findings provide the government with all the criteria essential for a valid approach to the sustainable development of the urban regions of the country and provide the appropriate balance between growth and development. The researcher recommended that creating supportive policies and incentives, investing in green infrastructure, supporting local entrepreneurship ecosystems, collecting and sharing data, and promoting community engagement are requirements for urban management. In addition, recommended that focusing on triple bottom line impact, collaborating with other stakeholders, Innovating and adapting, communicating transparently, and advocating for change are required for Sustainable Businesses by Entrepreneurs.

DOI: 10.22034/IJHCUM.2024.03.04

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
43	1	5

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

Entrepreneurship has been viewed as an impetus assistant acting in the direction of uplifting the economy by developing new firms and industries encountering several hurdles and ultimately surfacing generating several jobs. While on the other side entrepreneurship would include multiple aspects by taking up the reachable inputs and generating the sustainable output needed (Noor *et al*., 2021). Sustainable development in India has continued to be a much-rationalized affair not just among governments but even amongst the student community. In light of the rationale of urban management and enhancement, sustainable development stands as the primary facet for the success of the project. The committee that the government established for this project took into mind the fact that as the population of nations like India grows, so does the corresponding need for resources (Mougeot, 2006). Regardless of the profitable upliftment happening worldwide, there has been a simultaneous growth in financial, societal, and environmental pitfalls. Natural coffers' reduction and the detrimental impact of environmental decline, comprising of a few extreme deficiencies such as unavailability of ample amounts of fresh drinking water (Samimi and Moghadam, 2024), loss of biodiversity, and draught, are some of the highlighted and brought to notice critical issues that need immediate attention for sustenance and survival (Greco, 2017).The term, sustainable refers to enhancing the current scenario for an even more developed foreseeable future. This has become even more vital in the context of the urban arena to deploy more environment-friendly protocols that would end up in more practical monetary situations workable for the individuals of the urban sector. The target of the government is to revamp around 100 cities into smart cities all over the nation which would be sustainable in the coming future as well-being civilian amicable in the current reference. This project is an initiative in the direction of paving the path for India, which is to be recognized among the developed nationals in the world. The primary etiquette created by the central and state governments is to attain the target of uplifting the urban section of the nation by allotting the required monetary aid for core support and other requirements. A part of the output of the project was expected to be met by 2022, but now the vision can be expected to come to form by 2030 (Rai *et al*., 2020). Randhawa and Kumar (2017) studied the features that the incremental level of population, resulting in an increased range of pollution due to misuse of natural resources, has contaminated the environment at large. Government representatives should focus on the sustainable urbanization of metropolises. India has outgrown the rapid-fire urbanization developing nation where the government has initiated a smart megacity charge. The standard of smart megacities in India is been well explained in this study. The results of Randhawa and Kumar (2017) concluded that in India the development of the smart megacity is with the integration of Information communication technology with civic planning to attain quality of life. Several micro, small, and medium-sized enterprises (MSMEs) fail to provide importance to sustainability (Rudawska, 2019), and environmental deterioration is not a primary concern for various business managers (Haanaes *et al*., 2011). For example, the global textile industry recycles only 1% of its total production waste, resulting in losses totaling $1 billion annually. Generating sustainable quick fixes to environmental issues can provide entrepreneurial hopes across all industries (Schaltegger and Wagner 2011). For initial adopters, sustainability is a strategic driver that requires a top-down approach and has a positive impact on key stakeholders (Haanaes *et al*., 2011). Sustainability-oriented companies maintain a network of mutually beneficial relationships with stakeholders, and building such collaborative partnerships has a longer-term potential than operating solely on profit maximization principles (Viswanathan *et al*., 2007). Sustainability-oriented business processes connect a company's daily operations with social, economic, and environmental priorities and influence stakeholder management (Stolze *et al*., 2012). Companies that want to build sustainable production and consumption systems practice stakeholder management at multiple levels, such as individual, corporate, industry, and society (Gonzalez-Porras *et al*., 2021). Adams *et al*., (2016) mentioned that a sustainability-pushed invention technique involves enhancing merchandise, tactics, or practices to attain the particular cause of generating and figuring out social and environmental costs similar to monetary returns. Companies prioritize stakeholder relationships based on converting

collaboration dynamics, which affect their stakeholder engagement through the years, and they try to satisfy the expectations of their key stakeholders (Kujala *et al*., 2019). The social element of sustainability additionally consists of building social networks (Dempsey *et al*., 2011), and marketers create a complicated net of relationships to assist their sustainability ventures (Neumeyer and Santos 2018). Sustainable businesses flourish in the fertile ground of smart cities, fostering economic sustainability through cutting-edge technologies and innovative solutions (Cheraghipoor *et al.,* 2024). This combination highlights how important technology is to create smart cities, which are all-encompassing settings that are made to be open, automated, inclusive, scalable, safe, flexible, and simple to maintain. The winds of sustainable business model innovation sweep across organizations, bringing with them the power to transform. This creative force can breathe life into entirely new models, revitalize established ones, or even weave together different models into a cohesive tapestry. A redefined value proposition for customers, nestled within a fresh value framework that fuels the organization's journey towards sustainability. As technology accelerates and communities embrace its potential, entrepreneurial ecosystems within smart cities are buzzing with novel business models nurtured by these advancements (Khademi *et al.*, 2014). This trend of digitizing businesses serves as a powerful tool for innovation, potentially leading to a wave of positive impacts. Imagine a landscape where businesses leverage cutting-edge technology to offer personalized, efficient, and sustainable solutions tailored to the unique needs of smart city residents. This vision paves the way for exciting possibilities, but it's crucial to remember that responsible development and inclusive access are key to ensuring these benefits reach all corners of the community. Far from mere economic models, these innovative business structures wield the power to become decision-making engines and economic planning tools for smart city management. They empower urban authorities to navigate the complexities of their cities, optimizing their services to strike a delicate balance: economic viability, social inclusivity, and environmental sustainability. Imagine leveraging data-driven insights to tailor public transportation based on real-time demand, maximizing efficiency while ensuring equitable access for all. This is the transformative potential that new business models unlock for smart cities. The United Nations 2030 proposal and the Sustainable Development Goals (SDGs) aims and supportability research is presently getting increasing consideration from the logical, political, and neighborhood decision-making organizations, which illustrates the need for organizations to rethink urban necessities to arrange to include social and natural issues that influence society as an entirety under consideration (Wolifson and Drozdzewski 2017; Mu *et al*., 2022).Urban entrepreneurship, which is regularly connected to urban revitalization of the economy, society, and environment, plays a progressively critical part in cities where it empowers the advancement of neighborhood businesses and social systems by capturing unmistakable and intangible assets and drawing speculation and individuals to places. In arrange to form extra esteem, unused urban strategies therefore receive a technique that's centered on business enterprise and neighborhood systems (Franco and Rodrigues 2022; Hashmi *et al*., 2023). Cities worldwide seek to become more astute as a portion of their key and inventive urban plans based on tending to existing urban issues and dangers (Chong *et al*., 2018). Various studies and research have inspected the association between urban enterprise and supportability, with empirical proofs, and found that businesses affect maintainability (Azmat 2013; Dana *et al*., 2022; Youssef *et al*., 2018). Also, a couple of have been conducted to uncover the relationship between open administration and maintainability. Outstanding among these ponders are Pinz *et al*., (2018) and Bessant *et al*., (2015) who found that open administration activities profoundly impact supportability motivation, be that as it may, there exists a crevice in writing on the nexus of urban business, open administration and supportability in a single ponder (Begum *et al*., 2022; Fu *et al*., 2023; Hashmi *et al*., 2023). Due to the large concentration of individuals in urban zones, people who act entrepreneurial in such ranges can be called urban entrepreneurs (Ziyae *et al*., 2021). Subsequently, the business incorporates the exercises of the people related to making unused organizations (Gërguri-Rashiti 2017). The urban business enterprise gives a prolific ground for understanding unemployment and its issues for cities. Hence, later talks of financial

geology have progressively centered on urban imagination and the significance of imagination in accomplishing financial development (Yu *et al*., 2020; Crittenden *et al*., 2019). In Smart cities, expanding financial development and social improvement are sought after through mechanical advancement (Sarma and Sunny 2017) and with the steady alteration in innovation and society, savvy cities offer thoughts for urban development and future advancement ways (Jiang *et al*., 2020). In connection with the shrewd city, businesses must alter the way values are made, displayed and ingested in natural, social and financial points of view. In this way, support in economic improvement forms can move forward commerce execution and make shared-value concepts (Morioka *et al*., 2022). In arrange to move towards a maintainable trade show, imaginative exercises are basic to making economic values (Goni *et al*., 2021). The current study focused on how urban regions have changed and how sustainable development helps cope with the changes. Furthermore, the study focused on enhancing the well-being of urban communities and promoting inclusivity to develop sustainable businesses that are economically sustainable in the long run. In comparison to previous studies of Brown and McGranahan (2016), this study aims to provide a more comprehensive understanding of urban challenges and proposes innovative solutions by synthesizing and building upon existing knowledge. This study was conducted during the academic year 2023-24 at Presidency Business School, Presidency College (Autonomous), Bangalore, Karnataka, in India.

Contextual background of the study

Urban areas in India are witnessing exponential growth, fueled by factors such as rural-urban migration, population expansion, and economic opportunities. This urban expansion has led to increased pressure on natural resources, infrastructure, and public services, posing significant challenges for sustainable urban development. Issues such as air and water pollution, inadequate waste management, and limited access to basic amenities underscore the urgent need for holistic urban management strategies.

Research gap and objectives

Despite the growing recognition of the importance of entrepreneurship in urban development, there exists a significant gap in the literature regarding the intersection of urban management, entrepreneurship, and sustainable development in India. This study seeks to bridge this gap by providing a comprehensive understanding of urban challenges and proposing innovative solutions to promote sustainable urban development. Specifically, the objectives of the study are to:

1. Explore the evolving dynamics of urban regions in India and the challenges they face in the context of sustainable development.
2. Examine the role of entrepreneurship in addressing urban challenges and fostering sustainable business practices within urban environments.
3. Identify innovative strategies and best practices for integrating entrepreneurship into urban management frameworks to promote sustainable urban development.
4. Assess the potential impact of these strategies on enhancing the well-being of urban communities and promoting inclusivity in urban development initiatives.

Hypothesis

Hypothesis 1: Effective urban management strategies have a positive impact on shaping sustainable practices within urban environments, and verify whether there is any significant relationship between urban management and sustainable practices in urban environments.

Hypothesis 2: Sustainable practices play a pivotal role in driving urban development toward sustainability, and verify whether there is any significant relationship between sustainable practices and urban development towards sustainability.

Significance of the study

This study holds significant implications for policymakers, urban planners, entrepreneurs, and other stakeholders involved in urban development initiatives in India. By shedding light on the role of entrepreneurship in promoting sustainable urban development, the findings of this study will inform policy decisions, guide urban planning strategies, and inspire innovative solutions to address pressing urban

challenges. Ultimately, the study aims to contribute to the advancement of knowledge in the field of urban management and entrepreneurship, with a focus on fostering inclusive and sustainable urban development in India.

MATERIALS AND METHODS

Study area

The study's main focus was on sustainable urban management techniques in a few Indian metropolises. The area made up of a densely populated urban agglomeration and its environs that share infrastructure, commercial spaces, transportation hubs, industrial zones, and residential regions is known as a metropolitan city. The chosen cities provide a mix of dry and wet tropical weather due to their diverse geographic location, with a humid tropical climate found in the northern regions. The chosen study area is located north of the equator and spans latitudes 8°4' to 37°6' north and longitudes 68°7' to 97°25' east (Fig. 1). Metropolitan cities have larger and more diverse populations than smaller cities or rural areas. This can make them more generalizable to other large cities, and it can also allow researchers to study a wider range of phenomena. Amritsar, Delhi, Agra, Varanasi, Kolkata, Udaipur, Jaisalmer, Jaipur, Mumbai, Pune, Hyderabad, Panaji, Mysore, Chennai, Bangalore, Kochi, and Madurai were the Indian cities chosen for the study.

Survey design and data collection

In the Indian context, unraveling the intricate link between urban management and sustainable business ventures by entrepreneurs necessitates a judicious blend of quantitative and qualitative research tools. The cornerstone of this investigative endeavor lies in well-crafted surveys, strategically designed to encompass distinct sections capturing comprehensive insights into entrepreneur profiles, their adopted sustainable practices, perceptions of urban management support, and encountered challenges or opportunities. The inclusion of diverse question types such as multiple-choice, Likert scales, ranking, and open-ended prompts ensures the collection of both numerical and textual data, thereby weaving a rich tapestry of nuanced insights. To augment this primary data, secondary sources in the form of government reports, policy documents,

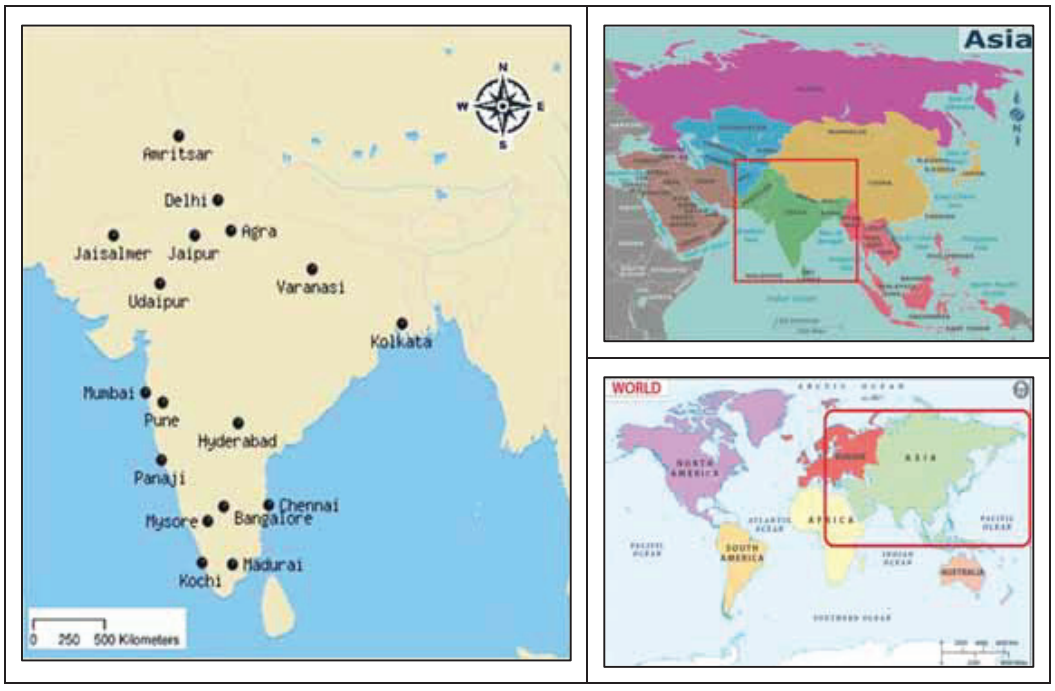

Fig. 1: Geographic location of the study area: India's metropolitan cities

and statistical resources on urban management and sustainable business practices provide a broader contextual understanding.

Entrepreneurs

Various diverse questions for entrepreneurs are

• Multiple Choice: Which sustainable practices do you currently implement in your business? (a) Waste reduction (b) Renewable energy (c) Water conservation (d) All of the above.

• Likert Scale: To what extent does your city's urban management support sustainable businesses? (Strongly disagree and strongly agree)

• Open-Ended: What are the most significant challenges you face in integrating sustainability into your business model?

• Rank/Rate: Rank the following factors in terms of their importance for encouraging sustainable businesses in your city: (1 - Most important, 5 - Least important) (a) Financial incentives (b) Regulatory support (c) Technical assistance (d) Public awareness campaigns

Urban management officials

Various diverse questions for urban management officials are

• Multiple Choice: What types of policies or initiatives does your city have in place to promote sustainable business practices? (a) Green building codes (b) Waste management programs (c) Tax breaks for sustainable businesses (d) All of the above.

• Open-Ended: How do you collaborate with entrepreneurs to implement sustainable urban development initiatives?

• Rank/Rate: Rank the following challenges in preventing effective support for sustainable businesses in your city: (1 - Most challenging, 5 - Least challenging) (a) Limited budget (b) Lack of awareness among entrepreneurs (c) Difficulty enforcing regulations (d) Insufficient data on sustainability impacts

Analytical framework

The analytical approach is two-pronged: quantitative data undergoes statistical methods like regression analysis to unveil relationships between variables, while qualitative data undergoes thematic analysis to identify central themes and recurring patterns in interview transcripts and observation notes. Throughout this empirical exploration, ethical considerations, including informed consent, data confidentiality, and strict adherence to research guidelines, remain paramount. The survey instrument undergoes a rigorous pilot test, the sources are triangulated for corroboration, and a reflective stance is maintained on potential biases and limitations of the study. By wielding these materials and methods with precision, the ensuing empirical study promises to illuminate the critical interplay between urban management and the burgeoning ecosystem of sustainable entrepreneurship in India. The use of statistical software, specifically SPSS, adds rigor to the quantitative data analysis process, further ensuring the reliability and validity of the findings.

RESULTS AND DISCUSSION

Statement on urban management

Table 1 shows the mean, Standard Deviation (SD), and priority ranking for the Statements on Urban Management. "I trust my city's government to effectively manage public resources" got first rank with a mean value of 5.04. "I feel like I have a voice in shaping the future of my city" got second rank with a mean value of 4.99. "My city is well-equipped to

Table 1: Statements on urban management

Statements	Mean	SD*	Priority ranking
I trust my city's government to effectively manage public resources	5.04	1.523	1
My city is well-equipped to handle unexpected challenges like natural disasters or pandemics	4.96	1.547	3
My city prioritizes environmental sustainability in its urban planning	3.61	1.977	6
My city offers residents easy access to recycling and waste disposal options	3.29	1.188	7
The availability of parks and green spaces in my city contributes positively to my mental and physical well-being	4.48	1.693	5
My city government effectively communicates with residents about important decisions	4.87	1.488	4
I feel like I have a voice in shaping the future of my city	4.99	1.380	2

*SD: Standard deviation

handle unexpected challenges like natural disasters or pandemics" got the third rank with a mean value of 4.96. "My city government effectively communicates with residents about important decisions" got the fourth rank with a mean value of 4.87. "The availability of parks and green spaces in my city contributes positively to my mental and physical well-being" got fifth rank with a mean value of 4.48. "My city prioritizes environmental sustainability in its urban planning" got the sixth rank with a mean value of 3.61 and "My city offers residents easy access to recycling and waste disposal options" got the seventh rank with a mean value of 3.29.

Urban management factors

Urban management is an intricate field that takes many different aspects and factors into account. Urban planning, mobility and transit, housing, public health, social service, economic development, and community involvement are all included in urban management. For this study, some criteria are explained as follows.

Factor 1: Trust in government and crisis management

High positive loadings for statements about trusting the city government and its ability to handle unexpected challenges. Indicates a factor related to public trust in government and confidence in crisis management capabilities.

Factor 2: Green urban planning and communication

Positive loadings for statements related to environmental sustainability, green spaces, and effective communication with residents. Suggests a factor associated with urban planning that prioritizes sustainability and transparent communication.

Factor 3: Resident engagement and voice

Positive loadings for statements reflecting resident engagement and having a voice in shaping the future of the city. Indicates a factor related to citizen involvement and participation in urban decision-making.

Factor 4: Parks and well-being

Positive loadings for statements linking parks and green spaces to residents' well-being. Suggests a factor related to the positive impact of accessible parks and green areas on mental and physical well-being.

Factor 5: Miscellaneous governance aspects

Mixed loadings on various statements suggest a more diverse factor related to other aspects of urban governance.

Urban management is a multifaceted approach to efficiently plan, organize, and control the complexities associated with urban areas to ensure sustainable development and the well-being of residents. It involves the coordination of various sectors, such as land use, transportation, infrastructure, and environmental sustainability. The management of urban areas requires a comprehensive understanding of the dynamic interactions among social, economic, and environmental factors. Previous researchers have employed diverse methods and techniques, including quantitative analyses, case studies, and modeling, to explore urban management challenges and solutions, according to Robinson *et al.,* (2011). These studies have delved into topics such as smart city technologies, participatory planning, and resilient urban development. The insights gained from this research contribute valuable knowledge to urban policymakers and practitioners, aiding in the formulation of effective strategies for urban governance. What sets this study apart is its emphasis on a holistic and integrative approach to urban management, acknowledging the interconnectedness of various urban systems.

Statement on sustainable practices by entrepreneurs

Table 2 shows the mean, SD, and priority ranking for the sustainable practices by entrepreneurs. **"**The upfront costs of implementing sustainable practices can be a barrier for small businesses**"** got first rank with a mean value of 5.10. **"**Educating customers about the value of sustainable products and services can be challenging**"** got second rank with a mean value of 5.08. "My business actively reduces its energy consumption and uses renewable energy sources whenever possible**"** got the third rank with a mean value of 4.98. **"**I believe that building a sustainable business is essential for long-term success**"** got fourth rank with a mean value of 4.87. **"**We minimize waste generation and prioritize recycling and composting within our operations**"** got fifth rank with a mean value of 4.31 and **"**Collaboration with other sustainable businesses can provide valuable resources and support**"** got sixth rank with a mean value of 4.23."

Table 2: Statements on sustainable practices by entrepreneurs

Statements	Mean	SD	Priority Ranking
I believe that building a sustainable business is essential for long-term success	4.87	1.789	4
My business actively reduces its energy consumption and uses renewable energy sources whenever possible	4.98	1.603	3
We minimize waste generation and prioritize recycling and composting within our operations	4.31	1.564	5
Educating customers about the value of sustainable products and services can be challenging	5.08	1.698	2
The upfront costs of implementing sustainable practices can be a barrier for small businesses	5.10	1.694	1
Collaboration with other sustainable businesses can provide valuable resources and support	4.23	1.813	6

Sustainable practices factors

By incorporating sustainable practices into their business models and operations and encouraging a culture of sustainability throughout their organizations, entrepreneurs have a special potential to drive sustainability. Following are the explanations of several criteria for this study.

Factor 1: General support for sustainable business

High positive loadings for beliefs in the essential nature of sustainable business for long-term success. Indicates a factor related to the overall support and belief in the importance of sustainability for business success.

Factor 2: Energy efficiency and renewable sources

High positive loadings for statements related to reducing energy consumption and using renewable energy sources in business operations. Suggests a factor associated with sustainable energy practices within businesses.

Factor 3: Waste minimization and recycling

Positive loadings for minimizing waste generation and prioritizing recycling and composting. Indicates a factor related to sustainable waste management practices within business operations.

Factor 4: Customer education and challenges

High positive loadings for statements about educating customers on sustainable products and the challenges associated with them. Suggests a factor related to the difficulties and importance of educating customers about sustainability in products and services.

Factor 5: Barriers and collaboration

Mixed loadings on statements about barriers to sustainable practices and collaboration with other sustainable businesses. Indicates a more diverse factor related to challenges and opportunities in sustainable business practices.

Sustainable practices encompass a range of strategies aimed at meeting the needs of the present without compromising the ability of future generations to meet their own needs. Previous studies have examined various sustainable practices across different sectors, including energy, agriculture, transportation, and construction. These studies have highlighted the importance of reducing carbon emissions, promoting renewable energy sources, adopting eco-friendly agricultural methods, and implementing green building technologies. In comparison to earlier research, the present study builds upon these findings by emphasizing a more integrated and cross-sector approach to sustainability. The results of the current study reveal that a comprehensive and interconnected strategy is crucial for achieving sustainable outcomes. By synthesizing insights from previous studies and proposing a more holistic perspective, this research contributes to a more nuanced understanding of sustainable practices and offers a roadmap for a more effective and harmonized implementation of sustainable strategies across diverse sectors. This approach addresses the interconnected nature of sustainability challenges and underscores the need for collaborative efforts to foster a resilient and environmentally friendly future.

Regression analysis between urban management and sustainable business by entrepreneurs

Regression analysis is a useful tool for

Table 3: Regression analysis between urban management and sustainable business by entrepreneurs

Variables	B	SE	Beta	T	P
Urban management	1.286	0.621	0.116	2.071	0.0039
Sustainable practices	1.088	0.257	0.238	4.242	0.0001

comprehending and controlling the intricate dynamics of urbanization. Making better decisions on urban development and management can be aided by its insightful information about the relationships between various elements. Regression analysis can be used, from the perspective of urban management, to forecast the increase of the urban population based on variables such as past population statistics, economic growth, and urban development strategies. This can assist legislators and urban planners in making well-informed choices about housing, infrastructure development, and other urban services. Planning and development plans for land use can be optimized with the aid of regression analysis. Regression analysis is a useful tool for evaluating how different urban policies and interventions affect outcomes like economic development, crime rates, and air quality. Regression analysis can also be used to predict the growth of the urban economy based on variables like investment trends, income levels, and employment rates. One useful technique for entrepreneurs looking to create long-lasting companies is regression analysis. Entrepreneurs may estimate future performance and determine the critical aspects that go into measuring the impact of sustainability initiatives by employing regression analysis. Additionally, entrepreneurs can recognize and comprehend the essential elements that support sustainability and profitability by employing regression analysis. Regression analysis can be used to determine which elements have the biggest effects on the performance of the business to improve resource allocation. Regression analysis can be used to pinpoint areas that need improvement by figuring out what exactly is hurting the company's performance. In this study, the regression analysis has been performed between urban management and sustainable business by entrepreneurs, and the results are presented in Table 3.

The first row of Table 3 shows the results for the independent variable "urban management". The coefficient of the urban management variable is 1.286, and the p-value is 0.039. This means that the urban management variable is statistically significant at the 0.05 level. The fact that the coefficient of the urban management variable is positive means that there is a positive relationship between urban management and the dependent variable. In other words, as urban management increases, the dependent variable also increases. The second row of Table 3 shows the results for the independent variable "Sustainable practices". The coefficient of the sustainable practice variable is 1.088, and the p-value is 0.0001. This means that the sustainable practices variable is statistically significant at the 0.05 level. The fact that the coefficient of the sustainable practices variable is positive means that there is a positive relationship between sustainable practices and the dependent variable. Regression analysis Standard Error (SE) provides information about the overall fit of the regression model, the width of confidence intervals, statistical significance, and accuracy of coefficient estimations. It is an essential tool for analyzing regression analysis data and drawing defensible conclusions from it. The study's urban management and sustainable practices were determined to have standard errors of 0.621, and 0.257, respectively (Table 3). The sustainable methods had the least amount of standard error, followed by urban management. For sustainable practices, a smaller standard error denotes a more accurate estimate of the coefficient, higher statistical significance, a narrower confidence interval, better model fit, and more testing power for hypotheses. In regression analysis, a smaller standard error is often preferred as it denotes a more accurate and dependable assessment of the relationship between the variables. Regression analysis was performed to make a model to foresee the relationship between urban management and sustainable business by entrepreneurs and the results are presented in Table 4. The accompanying Regression model was viewed as affirming the connection between Independent and dependent variables (Samimi and Nouri, 2023).

The percentage of the dependent variable's variation that can be predicted from the independent variables is shown by the coefficient of determination (R^2), in regression analysis (Samimi and Mansouri,

Table 4: R and R^2 value between urban management and sustainable business by entrepreneurs

R	R^2	F	p
0.899	0.808	11.910	0.0001

2024). From Table 4, it may be observed that the value of R^2 (0.808) shows the change of the dependent variable being clarified by the independent factors and the worth of F (11.910) displays the significant relationship. The worth of F static affirms the wellness of the model. The R value (0.899) represents a solid connection between the independent and dependent factors. The R^2 also represents the autonomous factors like urban management and sustainable practices collected for the model together. The correlation coefficient (R) is 0.899, which indicates a strong positive correlation between the two variables. Even though the coefficient of determination is 0.808, the other variable accounts for 80.8% of the variance in the main variable. The study found a limited correlation between sustainable entrepreneurs and urban management, as indicated by the low value of R^2. The results of this research indicated that, given the low R^2, it could be necessary to speculate on whether any other variables should be taken into account when analyzing the relationship between sustainable practices and urban management. However, the connection is statistically significant as indicated by the F-statistic of 11.910, which is significant at the p-value of 0.0001.

Vari max rotated component matrix between urban management and sustainable business by entrepreneurs

By maximizing the variance of the squared loadings inside a factor, the Varimax rotation seeks to simplify factor interpretation and facilitate the identification of the main variables connected to each component between urban management and sustainable business entrepreneurs. This can be especially helpful in urban management when determining the major elements influencing quality of life, sustainability, or urban development. Understanding the fundamental elements that affect other facets of urban management, such as infrastructure, transportation, economic development, and environmental quality, can also be aided by this. Additionally, the Vari Max Rotated Component Matrix (VMRCM) is a tool that aids in the identification and interpretation of the underlying elements influencing urban management by academics and urban planners. This information can be used to design policies and make decisions that are more effectively informed. For sustainable business shareholders, the Vari Max Rotated Component Matrix can be a useful tool for determining the fundamental elements that support sustainability and company success, assessing the success of sustainability programs, and spotting areas where their sustainability efforts can be strengthened. Through the examination of the rotational component matrix, entrepreneurs can determine which variables are not influencing the elements crucial for sustainable business practices and prosperity, offering them valuable perspectives on places in which to concentrate on their efforts to enhance sustainability. Data often contains underlying factors that influence multiple variables. These factors might represent broader concepts or latent constructs that aren't directly measured. Factor analysis helps us identify these hidden factors by statistically examining the correlations or inter-relationships between the observed variables. Table 5 displays the results of a Vari Max rotation applied to a factor analysis of different variables. By analyzing the loadings (values between -1 and 1), the study can identify underlying themes or factors that explain the relationships between the original variables. Table 5 shows the loadings of variables on extracted factors after Varimax rotation. Rotated Components for the Urban Management (RCUM) of various factors are designated as RCUM1, RCUM2, RCUM3, RCUM4, RCUM5, RCUM6, and RCUM7 for the urban statements 1, 2, 3, 4, 5, 6, and 7, respectively. Similarly, Rotated Components for the Sustainable Practices (RCSP) of various factors are designated as RCSP1, RCSP2, RCSP3, RCSP4, RCSP5, and RCSP6 for the sustainable practice statements 1, 2, 3, 4, 5, and 6, respectively. Vari max rotated component matrix between urban management and sustainable business by entrepreneurs is presented in Table 5.

From Table 5, it may be observed that RCUM1 was strongly correlated to "I trust my city's government to effectively manage public resources" of the urban

Table 5: Vari max rotated component matrix between urban management and sustainable business by entrepreneurs

Factors	1	2	3	4	5
Urban management					
I trust my city's government to effectively manage public resources	0.945	-0.110	0.059	-0.028	-0.037
My city is well-equipped to handle unexpected challenges like natural disasters or pandemics	0.884	-0.110	0.059	-0.028	-0.037
My city prioritizes environmental sustainability in its urban planning	0.815	-0.107	-0.284	-0.172	0.210
My city offers residents easy access to recycling and waste disposal options	0.739	0.905	-0.101	-0.033	-0.175
The availability of parks and green spaces in my city contributes positively to my mental and physical well-being	0.600	0.905	-0.101	-0.033	-0.175
My city government effectively communicates with residents about important decisions	0.538	-0.447	-0.204	-0.140	-0.187
I feel like I have a voice in shaping the future of my city	0.514	-0.433	0.221	0.268	0.305
Sustainable practices					
I believe that building a sustainable business is essential for long-term success	0.133	0.7617	0.924	-0.075	0.043
My business actively reduces its energy consumption and uses renewable energy sources whenever possible	0.133	0.6854	0.924	-0.075	0.043
We minimize waste generation and prioritize recycling and composting within our operations	-0.412	0.6665	0.502	-0.052	-0.119
Educating customers about the value of sustainable products and services can be challenging	-0.018	0.6417	-0.079	0.952	-0.086
The upfront costs of implementing sustainable practices can be a barrier for small businesses	-0.018	0.6215	-0.079	0.952	-0.086
Collaboration with other sustainable businesses can provide valuable resources and support	0.173	0.6121	0.007	0.470	0.129

management statement. RCUM1 was moderately correlated to urban statements 2, 3, and 4. Less was correlated to 5, 6, and 7 of the urban management statements. RCUM2 was strongly contributed by urban statements 4 and 5, which may be related to “my city offers residents easy access to recycling and waste disposal options” and “the availability of parks and green spaces in my city contributes positively to my mental and physical well-being”. RCUM3, RCUM4, and RCUM5 did not influence any of the statements mentioned for urban sustainability management. But, moderately correlated with the urban management statement, “I feel like I have a voice in shaping the future of my city”. Furthermore, from Table 5, it may also be observed that RCSP2 had a positive correlation with sustainable practices from 1 to 6, and RCSP2 was strongly correlated with the sustainable practice statement “I believe that building a sustainable business is essential for long-term success”. The RCSP2 was moderately correlated with other sustainable practices, from 2 to 6. Whereas, all other factors (RCSP1, RCSP3, RCSP4, and RCSP5) were less correlated with all statements of sustainable practices. The overall observations made from Table 5 indicated that RCUM1 and RCSP2 were from strongly to moderately, correlated with the overall statement of both urban management and sustainable practices.

RECOMMENDATIONS

The study made some recommendations on sustainable practices for sustainability as well as urban management based on its findings.

For urban management:

Urban management in the context of sustainable business by entrepreneurs can be defined as the set of strategies, policies, and actions aimed at effectively planning, organizing, and governing urban resources and activities to promote economic development,

social equity, and environmental sustainability within urban areas. It involves coordinating various stakeholders, including entrepreneurs, local government, and communities, to achieve sustainable urban development goals.

• Encouraging green infrastructure development: Promoting the use of renewable energy sources, implementing green building practices, and creating green spaces within urban areas to enhance environmental sustainability and support sustainable businesses.

• Facilitating collaboration and networking: Fostering partnerships between entrepreneurs, local government, academic institutions, and community organizations to share resources, knowledge, and best practices for sustainable business development.

• Implementing supportive policies and incentives: Introducing policies that incentivize sustainable business practices, such as tax breaks for eco-friendly businesses or subsidies for renewable energy initiatives, to encourage entrepreneurship and innovation in sustainability.

• Promoting technology adoption: Encouraging the adoption of innovative technologies, such as IoT devices for energy management or blockchain for supply chain transparency, to improve efficiency and reduce environmental impact in urban businesses.

• Support local entrepreneurship ecosystems: Invest in incubators, accelerators, and mentorship programs tailored to sustainable businesses. Facilitate access to funding, co-working spaces, and networking opportunities.

• Collect and share data: Track the impact of sustainable businesses on economic, social, and environmental indicators. Share data publicly to inform policy decisions and attract further investment.

• Promote community engagement: Encourage dialogue between residents, businesses, and local government to identify shared sustainability goals and develop inclusive solutions.

For sustainable businesses by entrepreneurs:

• Focus on triple bottom line impact: Measure and report on economic, social, and environmental performance. Prioritize practices that benefit community well-being, such as fair wages, local sourcing, and inclusive hiring.

• Collaborate with other stakeholders: Partner with local non-profits, government agencies, and academic institutions to leverage expertise and resources. Explore collective efforts like shared supply chains or joint marketing initiatives.

• Innovate and adapt: Continuously seek new technologies and business models that enhance sustainability and address community needs. Embrace experimentation and pilot projects to learn and evolve.

• Communicate transparently: Share your sustainability values and impact stories with stakeholders. Foster understanding and trust through engaging communication channels.

• Advocate for change: Participate in policy discussions and support organizations working towards a more sustainable future. Raise awareness about the positive role of sustainable businesses in urban communities**.**

Addressing the Role of Local Government and Policymakers:

• Creating a conducive regulatory environment: Developing policies and regulations that support sustainable business practices, streamline permitting processes for eco-friendly businesses, and ensure compliance with environmental standards.

• Providing financial support and resources: Offering grants, loans, or subsidies to entrepreneurs for implementing sustainable business initiatives, conducting research and development in sustainable technologies, or participating in training and capacity-building programs.

• Facilitating access to markets and networks: Facilitating access to local and global markets, providing networking opportunities with potential partners and investors, and promoting collaboration between sustainable businesses and other stakeholders in the urban ecosystem.

While Indian cities face challenges in achieving sustainability, "Urban Management and Sustainable Business by Entrepreneurs" shines a light on the potential of entrepreneurial solutions. The study concludes that harnessing the power of innovative businesses, coupled with supportive government policies and collaborative efforts, can unlock a brighter future for urban India. Entrepreneurs, armed with diverse business models like circular economy ventures and resource-efficient technologies, are key players in tackling environmental and social challenges. However, their success hinges on a supportive

ecosystem. Clear, long-term government policies that incentivize sustainability and streamline regulations are vital. Collaboration between entrepreneurs, NGOs, and government agencies unlocks knowledge, resources, and best practices for broader impact. Living in densely populated urban centers sparks a unique brand of entrepreneurial spirit, giving rise to the distinct phenomenon of "urban entrepreneurs" (Ziyae *et al*., 2021). By harnessing the city's inherent dynamism and resource diversity, these enterprising individuals offer innovative solutions that not only tackle urban unemployment but also fuel economic growth. This growing trend has captivated the attention of economic geographers, who highlight the crucial role of urban creativity in unlocking a city's economic potential (Yu *et al*., 2020; Crittenden *et al*., 2019). The rise of digital technologies has become a potent force in reshaping urban governance. Transforming cities into data-driven landscapes fuels not only the optimization of governance processes but also contributes to capital accumulation for further urban development. However, this burgeoning trend towards smart cities, heavily reliant on technological solutions, services, and infrastructure, risks reinforcing a singular ideology that can potentially narrow the scope of urban decision-making, potentially leading to homogenized outcomes across diverse urban contexts (Ziyae *et al*., 2021). Equally important is ensuring inclusivity and equity. Sustainable initiatives must empower marginalized communities, providing equitable access to resources and benefits. Standardized metrics and participatory planning processes further strengthen the impact of these initiatives. By empowering entrepreneurs, fostering innovative business models, and ensuring effective urban management, the study paves the way for a future where Indian cities thrive – environmentally responsible, socially just, and economically vibrant. The journey towards this vision requires continued research and active collaboration, but the potential rewards are immense. Let's embrace the power of entrepreneurship and chart a sustainable course for India's urban future. The findings underscore the critical role that entrepreneurs play in shaping urban landscapes and fostering sustainability. Firstly, it is evident that successful urban management and sustainable business practices are intertwined, with entrepreneurs serving as key actors in driving positive change. The study reveals a growing awareness among Indian entrepreneurs regarding the importance of integrating sustainable practices into their business models. This shift is not only driven by ethical considerations but also by a recognition of the long-term economic benefits associated with environmentally responsible practices. Additionally, the study highlights the challenges faced by entrepreneurs in navigating the complex landscape of urban development policies and regulations. There is a need for greater collaboration between entrepreneurs and government bodies to create an enabling environment that supports sustainable business practices. Overall, the empirical evidence suggests that a holistic and collaborative approach involving entrepreneurs, policymakers, and other stakeholders is essential for fostering urban sustainability in the Indian context. This research contributes to the ongoing discourse on sustainable business and urban management, providing practical insights that can inform both policy and entrepreneurial decision-making for a more sustainable and resilient future.

CONCLUSION

The empirical study on urban management and sustainable business by entrepreneurs in the Indian context yields valuable insights into the intersection of economic development, environmental considerations, and entrepreneurial endeavors. The findings underscore entrepreneurs' proactive adoption of sustainable practices, focusing on waste management, energy efficiency, and social responsibility. This highlights innovation's crucial role in fostering balanced urban growth and development through holistic approaches beyond profit. The novelty of the study lies in its exploration of how sustainable development can mitigate the impacts of urban change and enhance community well-being and inclusivity. By shedding light on the proactive stance of entrepreneurs towards sustainable business practices and their critical role in shaping urban landscapes, the study contributes to the ongoing discourse on sustainable business and urban management. The significance and value of the study are twofold. Firstly, it emphasizes the importance of integrating sustainable practices into entrepreneurial endeavors, not only driven by ethical considerations but also recognizing the long-term economic benefits. Secondly, the study highlights the need for greater collaboration between entrepreneurs and

government bodies to create an enabling environment that supports sustainable business practices. These insights have practical implications for policymakers, entrepreneurs, and other stakeholders, informing decision-making processes for a more sustainable and resilient urban future in India.

AUTHORS CONTRIBUTION

K. Ravindran handled the literature review, analysis, and interpretation of the data. The review was revised and written under the supervision of C.A. Chandan and offered expertise and insights into the research design and methodology. D. Sivakumar provided insightful commentary to ensure the manuscript's technical soundness. A.S.B. Inayath collected the data and finished writing portions of the text. T. Dhanabalan conducted statistical analysis of the collected data, applying appropriate methods to analyze relationships between variables. Both the literature review and a portion of the manuscript preparation were done in part by V. Kumaresan.

ACKNOWLEDGEMENT

The Presidency College (Autonomous), Bangalore, India; Kalasalingam Academy of Research and Education, Krishnankoil, India; and Knowledge Institute of Technology, Salem, India are acknowledged by the authors of the present investigation for their unflinching support during the entire research process.

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.

ABBREVIATIONS	DEFINITION
%	Percent
MSME	Micro, Small, and Medium-sized Enterprises
RCSP	Rotated Components for Sustainable Practices
RCUM	Rotated Components for Urban Management
SDG	Sustainable Development Goals
SD	Standard Deviation
SE	Standard Error
VMRCM	Vari Max Rotated Component Matrix

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HOW TO CITE THIS ARTICLE

Ravindran, K.; Chandan A.C.; Sivakumar, D.; Inayath Ahamed S.B.; Dhanabalan, T.; Kumaresan V., (2024). Urban Management and Sustainable Business by Entrepreneurs. Int. J. Hum. Capital Urban Manage., 9(3): 413-428.

DOI: 10.22034/IJHCUM.2024.03.04

URL: https://www.ijhcum.net/article_711784.html

Int. J. Hum. Capital Urban Manage., 9(3): 429-446, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Designing the psychological safety model of knowledge workers in organizations

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ARTICLE INFO

Article History:
Received 18 August 2023
Revised 29 November 2023
Accepted 31 December 2023

Keywords:
knowledge workers
Mental health
Psychological safety
Tehran Municipality
Thematic analysis

ABSTRACT

BACKGROUND AND OBJECTIVES: Knowledge workers are people whose work is highlighted by the continuous and systematic development of organizational knowledge through the discovery mechanism and creation of new knowledge. The number of knowledge workers is increasing in today's organizations, and proper conditions must be provided for their activities. Also, the effective use of knowledge workers requires optimal psychological safety for them. So far, not so many studies have investigated psychological safety, especially for knowledge workers, and there is an obvious research gap in this field. Therefore, the innovation of this research is to increase knowledge about the psychological safety of knowledge workers and to create local and practical knowledge in the mentioned field.

METHODS: This research aims to design a psychological safety model for knowledge workers in the Tehran Municipality. The applied-developmental purpose aspect of this research puts it in the category of mixed (method) research. In the qualitative phase, a semi-structured method of interviewing experts, and thematic analysis techniques were used to design the research model. 18 experts from Tehran Municipality were purposefully selected to participate in the interviews. The model of the research was validated by structural equation modeling and Smart PLS software in the quantitative phase. For this purpose, 110 managers and specialists of Tehran Municipality were surveyed using a questionnaire.

FINDINGS: The results indicated that the personal, interpersonal, occupational, managerial, organizational, and spiritual dimensions are 6 dimensions that influence the psychological safety of knowledge workers in organizations. Also, several antecedents, moderating factors, and consequences were identified, which were created based on the identified variables of the research model. Also, the coefficient of determination was calculated as 0.740 for the psychological safety variable and 0.711 for the outcomes variable, based on the results of structural equation modeling, which indicates optimal values.

CONCLUSION: Ultimately, the results of the research indicated that the psychological safety of knowledge workers is a complicated, multidimensional, and dynamic phenomenon, and achieving it requires considering several factors and components, and of course, it brings valuable results.

DOI: 10.22034/IJHCUM.2024.03.05

NUMBER OF REFERENCES

56

NUMBER OF FIGURES

3

NUMBER OF TABLES

7

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

In today's world, the emergence of the knowledge-based economy has brought new demands in organizations and made important changes in organizational goals and human resource practices (Akbar *et al*., 2021). In the current situation, it's important to know that the skills and abilities of employees are the key to the success of new organizations; therefore, the transition from the traditional economy to the knowledge-based economy provides an opportunity to prioritize the role of human resources in the organization (Moinian *et al*., 2021). In the modern and knowledge-based economy, organizations are required to use knowledge-based human capital to create and maintain a competitive advantage so that they can guarantee their survival and durability against technological changes through their creativity and ideation (Igielski, 2017). Knowledge workers are considered the most important capital of the organizations (Katalnikova, 2018). For knowledge workers, the social-psychosocial work environment comes with risks and opportunities to promote health and well-being (Chirico *et al*., 2019; Aronsson *et al*., 2017; Helland, 2022). On the other hand, knowledge workers are generally more expected to go through burnout, which prevents them from being productive, due to heavy workloads, decision-making situations, and continuous learning needs (Ocha Pacheco *et al*., 2023). Therefore, offering healthy work environments for knowledge workers can come with valuable results for organizations and society (Helland, 2022). Over the past three decades, job opportunities for knowledge workers have increased and accelerated in today's world due to the impact of globalization and intense competition. Because knowledge workers are the most important wealth creators in the current economy, organizations are seeking ways to ensure their optimal productivity. Since knowledge workers may be more knowledgeable and skilled compared to their superiors, understanding their work psychology and sociology is essential for management (Akbar *et al*., 2022). Also, knowledge workers face many challenges in their workplace, including scattered work activities, multiple disorders, complicated tasks, and long working hours. These challenges can affect the stress, concentration, and alertness of knowledge workers and in turn affect their interaction with the digital environment, the quality of their tasks, and generally their productivity (Soto *et al*., 2021). Mental health is known as a global challenge and one of the main leading causing factors of disease throughout the world (Elraz, 2018). Mental health and its problems are very important and exciting on social and organizational scales, as well as raising awareness of common mental health experiences around the world. However, there is a relative lack of knowledge about how mental health conditions are understood/implemented in companies (Elraz, 2018; Helland, 2022). Mental health can be considered a basic human need that affects the quality of life in general. On the other hand, mental illnesses cause huge economic losses worldwide. For example, Patel *et al*. (2018) estimated the global economic loss caused by mental illness on a global scale to be around 16 billion U.S. dollars between 2010 and 2030. Therefore, mental health may be considered an important variable, tied to ethical and economic aspects in the modern world of work (Stuber *et al*., 2020). Also, mental health disorders at the workplace, such as depression and anxiety, are increasingly recognized as a problem in the majority of countries. By using the human capital approach, the global economic burden of mental illness was estimated at 2.5 trillion U.S. dollars in 2010, which will be increased to 1.6 trillion U.S. dollars in 2030; certainly, this problem is majorly caused due to the loss of productivity (De Oliveira *et al*., 2023). Therefore, focusing on health promotion and prevention of health risks in the psychosocial-social work environment of knowledge workers is necessary for quality knowledge production and managing the health and well-being of employees (Helland, 2022). In its latest report, the International Monetary Fund stated Iran's GDP, to be 1,596 billion dollars in 2022, according to the purchasing power index, which is increased by 141 billion dollars compared to the year before, and Iran is the 22nd world's greatest economic power in 2022. Also, in Iran's 1404 vision plan for the improvement and development of the country, the knowledge-based economy has been emphasized, therefore, its main requirements are also extremely important: one of the main prerequisites for achieving the goals of the 1404 vision plan is the development of the competence of the intellectual capital of the organization. In the general policies of the administrative system, Iran's Supreme Leader (may he live long) has also emphasized the importance of

knowledge-basing the administrative system; also, in the 4th and 8th Macro strategies, from the national comprehensive scientific map, the institutionalization knowledge and the development of knowledge-based organizations, along with the training and empowerment of human capital, have been emphasized (Abedini *et al*., 2021). Also, in many national higher documents, the importance of developing knowledge and improving the performance of knowledge workers for organizations has been emphasized. Various types of organizations operate in Iran, based on typology, municipalities are non-governmental or public institutions (Khodadai Qale-Salimi *et al*., 2019). In Article 5 of Iran's Public Accounts Act, these institutions are defined: "public, non-governmental institutions and organizations based on this law are specific organizational units that are established or will be established with the permission of the law, to fulfill duties and provide services which hold a public aspect''(Sheikhi and Moradkhani, 2019). In recent years, the number of knowledge workers in organizations, especially in Tehran Municipality, has been increasing. These employees have their own special psychological and mental characteristics and conditions. Job satisfaction and its dimensions are different based on academic degrees in Tehran Municipality employees, and employees with higher knowledge and academic degrees usually have higher expectations in terms of job satisfaction (Osanloo Bakhtiari *et al*., 2021). Also, one of the current problems and challenges of Tehran Municipality with its knowledge workers is the lack of a clear career development path for them. In other words, preserving knowledge capita and using their experiences during their service is a challenge that is currently considered one of the most important needs of Tehran Municipality (Davarzani *et al*., 2020). The design of jobs and the organizational environment in Tehran Municipality have not significantly changed since the early 21st century, even though during this period, the number of knowledge workers in this organization has increased significantly (Asanlu Bakhtiari *et al*., 2021). Also, the anxiety level and high workload of the municipality employees interact with their intellectual concentration and personal development, as well as increasing their mental disorders (Alaee, 2016). In addition, the conditions of salary payment in Tehran Municipality don't consider much difference between employees in terms of knowledge and skills, and therefore, knowledge workers are not motivated to work harder (Ajal Afshar *et al*., 2021). As the number of knowledge workers in organizations continues to grow, research into this group has become increasingly important. Among the fundamental areas of study in this field is the concept of psychological safety, a topic that has garnered significant attention and discussion. Investigates psychological security among academic staff. It identifies strategies and actions to enhance psychological security, as well as the factors affecting it and its outcomes. Therefore, due to the presentation of a comprehensive and systematic model, it can answer many questions in the field of research. Therefore, conducting this research can provide the basis for the development of theoretical knowledge in the field of organizational behavior studies in general, and psychological security in particular. It can be used by professors, students, researchers, and others interested in scientific discussions in the field of organizational behavior. On the other hand, previous research on psychological security has been related to employees with average and low skills and knowledge, and less attention has been paid to the psychological security of academic staff. This makes the research topic innovative. In this study, human resource management, spiritual, and external organizational factors affecting psychological security, which have received less attention in previous research, are examined. Alongside this, efforts are made to more fully identify other factors (individual, interpersonal, occupational, managerial, and organizational) centered on academic staff, which is another innovation of the research. In addition, the discussion of psychological security in the municipal organization has not been raised so far, and considering the special organizational nature of the municipality, the research topic in this organization is a new discussion. Overall, it can be stated that organizations, especially Tehran Municipality, must provide proper conditions for the activity of their human resources, especially knowledge workers, and reduce their mental and physical pressures in the workplace as much as possible. On the other hand, workplace conditions put knowledge workers under the constant influence of mental, psychological, and physical pressures and stresses, and not only their performance is affected, but also they suffer many physical and psychological problems later on. Public

service organizations, including Tehran Municipality, are not an exception, and the employees of these organizations also suffer psychological stress in their work environments. Most of the weaknesses and inefficiencies of the employees in Tehran Municipality are not caused by the lack of knowledge and skills, but caused by mental and nervous pressure and stress, and result in a reduction in their mental health (Rezaei and Hosseini, 2014; Mirzaei *et al*., 2020). On the other hand, in Tehran Municipality, the employees have improved significantly in terms of academic degrees and job knowledge, and in other words, they are fulfilling tasks as "knowledge workers." Therefore, psychological safety in their jobs and being able to focus on solving the existing problems are an absolute must for them. Therefore, the results of the current research can be used to improve the performance of academic staff by creating psychological security for them in Tehran Municipality. In addition, by applying the research results, the groundwork for creating psychological security for the academic staff of Tehran Municipality is provided, subsequently improving their performance and better serve various stakeholders. As a result, conducting this research is necessary to meet the interests and expectations of the stakeholders of Tehran Municipality. In this article, after stating the problem and the necessity of the research in the introduction, the aim and innovation of the research are presented. The theoretical foundations are then elaborated in two sections: psychological security and academic staff, followed by a review of the research background. Subsequently, after stating the research method, the research findings are presented in two sections: qualitative (theme analysis) and quantitative (structural equation modeling). Finally, in the concluding section, after the discussion and conclusion, practical suggestions are presented. The research aims to provide a model for the psychological security of academic staff in Tehran Municipality. The main question of the present research is: What is the pattern of psychological safety of knowledge workers in Tehran Municipality?

Theoretical basis

Psychological Safety (PS)

Mental health is an important part of the general concept of health including the ability to communicate with others, adaptation to the environment, as well as knowing how to manage anxiety in everyday life when faced with critical conditions. Therefore, the mental health of an individual includes healthy behavior, beliefs, and thoughts (Rajabipour *et al*., 2022). Also, psychological safety is considered as a cognitive state, that doesn't result in risky behaviors or harm or threaten anyone's status, public image, or job (Nembhard and Edmondson, 2006). Psychological well-being refers to one's understanding of the coordination of themselves on the one side and the consequences of their performance on the other side. Psychological well-being is formed by 6 factors self-acceptance (having a positive attitude towards oneself), positive relationship with others (warmly communicating and close relationships with others and the ability to empathize), self-determination (feeling independent and being able to stand up against social pressures), purposeful life (having a goal in life and adding definitions to it), self-improvement (a sense of continuous improvement) and having control over the environment (a person's ability to manage the environment) (Ryff, 1995). Several factors in the workplace determine mental health, including employee stress, too many job requirements, low job control, low social support, the effort-reward imbalance, procedural or relational organizational justice, organizational change, job insecurity, temporary employment, unusual working hours, poor psychosocial-social safety and bullying (Akerstrom *et al*., 2021). Also, psychological safety includes 4 elements, which are: 1) senior management support and commitment, 2) prioritizing mental health by the management, 3) organizational communication, and 4) organizational participation and conflicts (Idris *et al*., 2012). On the other hand, the main factors of the psychological-social work environment include shift work, long working hours, repetitive tasks, no job control, high work requirements, lack of leadership, bullying, violence in the workplace, conflict between work and life, imbalance of the reward system and lack of justice in the organization (Hiesinger and Tophoven, 2019). These factors are mainly extracted from three theoretical models (1) job-demand control model, (2) effort-reward imbalance, and (3) organizational justice. The first model was proposed by Karasek Jr. (1979). He claimed that social support, psychological demand, and freedom in decision-making are necessary in all organizations. Another model was proposed by Siegrist (1996). According to this model, individual determination of effort and

reward balance is the fundamental factor. Elvainio *et al*.'s (2002) model emphasizes organizational justice as well. Many researchers have used these theoretical models to investigate health issues and their impact on employees (Harvey *et al*., 2017).

Knowledge Workers (KW)

The term knowledge workers was used by the great management philosopher, Peter Drucker, for the first time in 1959 (Arthur, 2008). Drucker (1999), stated that the most valuable asset of an organization in the 20th century was its production facilities and predicted that the most valuable asset of an organization in the 21st century would be its knowledge of workers and their efficiency. From Drucker's (1994) point of view, knowledge workers can be the ultimate key to competitive advantage for an organization. Drucker used the term knowledge workers to refer to the employees working with intangible resources. Since then, knowledge workers have been defined as high-ranking workers with scientific and analytical knowledge who are expected to develop new products and services. Knowledge work is complicated, and knowledge workers must hold special skills and talents, practical and theoretical knowledge, and be familiar with their field of activity. These employees are required to find information, access information, recall information, and apply information. Also, knowledge workers must nicely interact with other workers and have the ability and motivation to acquire and develop these skills as well. Although these characteristics can vary from one job to another, knowledge workers must have these basic conditions (kuzey, 2021). Knowledge workers are defined by three approaches (Mladkova *et al*., 2015): 1) conceptual approach (e.g., Peter Drucker's point of view) 2) job content approach (e.g., managers); and 3) industry approach (meaning people who work in knowledge industries). All three approaches share some defining characteristics, including using knowledge to create value and having an academic degree or an equivalent degree (Surawsky, 2019).

Some studies define knowledge workers as individuals who are qualified to gain information about the job more than anyone else in the organization. This type of employee can collect, mix, and use knowledge (Hoyos *et al*., 2016). Knowledge workers help organizations improve efficiency and achieve a competitive advantage in the market. Since organizations have realized the importance of knowledge workers in organizational development, management has focused on the job performance of knowledge workers, which ultimately results in the improvement of organizational performance (Bhatija *et al*., 2017). To ensure that knowledge workers are optimally efficient and can achieve their personal goals, they should have resources and services that meet their needs, especially in the physical and social environment (Palvalin *et al*., 2017). Also, factors affecting the productivity of knowledge workers can be categorized into two (Butt *et al*., 2018): organizational and individual factors. Organizational factors include company strategy, structure, quality of human resources and organization performance, and the ability to use knowledge of the staff by using tools, processes, and products, and as a result, the efficiency of innovation. Working on these organizational factors promotes three important ways to create brand-new knowledge and innovation: continuous improvement, continuous exploitation of knowledge, and true innovation. Individual factors are related to the knowledge workers and include intrinsic motivation, believing in the organization's mission, participating in knowledge management and task supervision, leading career learning, theoretical knowledge, analytical knowledge, formal training, mastering expertise in the field, communication skills, improving peace and stability, etc. (Butt *et al*., 2018).

Research background

A few local and foreign studies have investigated topics that are close to the research topic. Among the local studies, Shirazi and Mesri (2022) designed a local model of mental stress of employees in hospitals of Tabriz. In this research, the identified factors were categorized into two controllable (management, structural, and human) and uncontrollable (environmental and attitudinal) categories. The findings of Noorahmadi *et al*. (2022) research showed a significant connection between psychological safety and organizational commitment. In research, Alavi (2022) worked on finding out the factors influencing mental health based on physical activity in Navy workers. The results indicated that "depression", "stress and anxiety", "OCD" and "fear" were considered the most important components of mental health, and physical activity also had a positive and significant effect on mental health.

The findings of Amrollahi and Arami Ardakani's (2020) research on employees of Iran's oil industry, indicated the positive and significant connection of mental health with organizational virtue and positive individual behaviors, and the organizational bullying variable plays a moderating and opposite role in the relationship between organizational virtue variables and positive individual behaviors with mental health. Also, in another study, Golchin *et al*. (2019) investigated the aspects forming mental health in employees of electronic payment services companies. The results showed that the mental-psychological health structure of employees in Iran has four main dimensions, mental-psychological health based on the person's life, individual's mental-psychological health; social mental-psychosocial health, and occupational mental-psychological health. The findings of Tajabadi and Mohebi Menesh's research (2020) show a great impact factor of the spirituality variable of the workplace on the overall mental health of employees. Taheri (2018) also worked on compiling the framework of the psychosocial-social-therapeutic environment at Qom University of Medical Sciences and two affiliated organizations in another study and based on the findings, the dimensions include leadership, the role of expectations, loyalty to the organization, job demands, control at work, organizational culture and situation, balance between work and personal life, and social interactions. The results of Sepahvandd *et al*.'s research (2018) also showed a significant connection between perceived organizational support, the spirituality of the workplace, and self-efficacy and their components with psychological well-being. The findings of Mehdad *et al*.'s research (2015) showed a high correlation between the variables related to the psychological health of workplace components and dimensions of job alienation. Finally, the findings of Golparvar *et al*.'s study (2014) indicate a significant connection between occupational stress-causing factors with psychosocial-social needs and also a significant connection between psychosocial needs and overall performance. Among foreign studies, the results of De Oliveira *et al*. (2023) research suggest that poor mental health (commonly considered as depression and/or anxiety) is associated with low productivity (i.e., attending or not attending meetings). Also, according to the findings of Ochoa Pacheco *et al*.'s (2023) research, there is a significant connection between the psychological empowerment of employees and the emotional loyalty and task-based job performance variables. The research results of Kim et al. (2022) also showed that three different strategies positively affect job attitudes, mental health, and job performance: (1) task assignments according to one's ability; (2) trust beliefs, and (3) management coaching. The results of Mathibe and Chinyamurindi (2021) also showed a direct relationship between organizational citizenship behavior and employees' mental health. Also, this relationship is significant only through the mediating effect of workplace social support. Also, in Kuzey *et al*. (2021) research, six factors affect the job satisfaction of knowledge workers, including management attitude, organizational support, job security, reward and salary, working conditions, and work partners' attitude. In another research, Akbar *et al*. (2021), prioritized the psychological-social factors of the work environment for knowledge workers. The results of their study show that the high priority dimensions are: conflict, workplace bullying, unpleasant harassment, organizational justice, and violent threats. The results of the research background showed that despite the focus of previous studies on psychological safety in organizational environments, less attention has been paid to this issue among knowledge workers, and there is an obvious research gap in this field. Considering the increase in the number of studies on knowledge workers due to the increasing number of them in the organization, psychological safety is one of the basic topics in the field of knowledge worker studies. On the other hand, in Iran, and especially in Tehran Municipality, many local factors affect the psychological safety of employees; therefore, it is necessary to address psychological safety among knowledge workers of Tehran municipality and provide a local model in this field. The previous theoretical views and theories are mainly for countries with different conditions compared to Iran and cannot be used for this country and Tehran Municipality, which is an organization with special conditions and characteristics. Therefore, the present research is necessary to fill the existing research gap. This research was conducted in the Tehran Municipality in 2023.

MATERIAL AND METHODS

The purpose of this research is to design a model

Table 1: Descriptions of the statistic sample size

Factor	Number
Gender	
Male	82
Female	28
Academic degree	
Bachelor's degree	21
Master's degree	55
PHD	34
Work experience (in years)	
Less than 10	19
10-20	35
20-30	44
Over 30	12

of the psychological safety of knowledge workers in Tehran Municipality. Based on the purpose, this research is developmental-applied. Also, because this research is aimed at designing a psychological security model for knowledge workers of Tehran Municipality, which is something new, and not so many researchers have worked on it before, the current research is considered to be an exploratory type of research. Also, this research is considered a mixed type of research as well. In the qualitative phase of this research, semi-structured interviews with experts and the thematic analysis method are used to design the research model, and in the quantitative phase, the structural equation modeling method is used to validate the designed model.

18 experts and specialists of Tehran Municipality were the participants in the qualitative phase. To design the model, the participants were selected by using the purposeful sampling technique based on knowledge and expertise in connection with the research title, and semi-structured interviews were conducted with each of them based on the defined framework. It is worth mentioning that the process of interviewing the experts continued up until the theoretical saturation point was reached, and when the researcher realized that there were no new points to be obtained from the interviews, the interviews were stopped. The selection criteria of experts included at least owning a master's degree, over 5 years of management experience in Tehran Municipality, and familiarity with topics related to organizational behavior and organizational psychology. In the quantitative phase, to validate the model that was designed in the qualitative stage, the structural equation modeling technique and PLS smart software were used. Before beginning to model the structural equations, the adequacy of the sample size was tested using the KMO index and Bartlett's test, the normality of the data was examined using the Kolmogorov-Smirnov test, and the results showed that the sample size was sufficient and the data are being a good fit for the structural equation modeling calculations. The statistical sample in this phase was 110 managers and experts in the municipality. In the quantitative phase, the sample size was calculated using Cochran's formula, and the simple random method was used as the sampling method. Also, to collect data, the mode questionnaire was used, the validity of which was confirmed by 3 experts. The reliability of the questionnaire was also checked by Cronbach's alpha method, and 0.825 was acceptable as calculated. The characteristics of the statistical sample are in Table 1.

RESULTS AND DISCUSSION

In this research, the thematic analysis was used to design the research model. To do so, the obtained data from the semi-structured interviews with experts were analyzed with the thematic analysis technique. After that, based on Braun and Clarke's theory (2006), the taken steps for designing the research model with the thematic analysis technique are as follows.

Step 1 - Familiarity with the data: In this research, after the researchers conducted semi-structured interviews with the experts, they proceeded to extract their content. After taking notes, the researchers analyzed them only based on the views and opinions of experts, with total accuracy and away from any subjectivity and prejudice. Of course, in cases where the researchers had doubts about their

Table 2: The context of the interviews and the extracted cod for the psychological safety dimension of the employees

Row	Context of the interview	Code (index)
1	"An important part of the demotivation of knowledge workers is caused by the simplicity and ease of their tasks, and that anyone else, who is normally skilled, can do them as well."	The meaningfulness of the job
2	"Appropriate jobs for knowledge workers should be designed in a way to include a variety of tasks and responsibilities so that they are challenged and attracted."	Career richness
3	"If knowledge workers receive appropriate feedback about their working conditions, they can better their performance by working on the improvement of the existing problems and shortcomings and also, strengthening their abilities."	Job feedback
4	"The knowledge workers should be expected based on the level of authority assigned to them. Inadequacy puts individuals under mental pressure and stress and prevents them from acting in a suitable mental condition.	A proper balance of powers and tasks
5	Managers should not have unreasonable and excessive expectations from knowledge workers. This puts them under extreme psychological pressure and does not allow them to work with full concentration. Thus, the expectations should be realistic and adjusted according to what they provide for knowledge workers and the existing restrictions.	Balance between job demands and job resources
6	"Unfortunately, in many cases, we see that knowledge workers are employed in jobs that are unrelated to their educations, and proper conditions are not provided for them to be able to use what they have learned."	Connection of education and job
7	"In today's world, it has become so important that a person's job fits his life conditions and can properly balance their job requirements and family expectations."	Compatibility of work and personal life

understanding of the content, they tried to resolve the ambiguities by contacting the participants.

Step two - Creating initial codes: In this step, the researchers considered a code for each point or content mentioned by the experts that referred to a specific topic. The process of creating codes continued until the researchers made sure that there were no missed points left and all the codes were extracted. The text of the interview and the extracted codes for the components of the psychological safety variable of knowledge workers are presented in Table 2.

Step 3 - Looking for themes: After extracting the codes, the identified codes were categorized in the form of themes. The researchers identified codes that were similar in conceptual and content terms. They proceeded to create the fundamental themes after combining them. Also, the researchers combined the fundamental themes that had conceptual common parts, and as a result, the organizing themes were also identified. Therefore, the output of this step included the identification of fundamental themes and organizing themes.

Step 4 - Reviewing the themes: This step includes reviewing and refining the themes. First, the coded summaries are reviewed. Then, the validity of the themes of the data is considered. This step was finished after obtaining a satisfactory map of themes aligned with the extracted codes.

Step 5 - Defining and naming themes: Finally, after creating a satisfactory and acceptable map of themes by the researcher, in the fifth step, he titles the categories of themes.

Titling is based on the nature and content of the categories, and it was tried to set titles in a way to achieve the maximum coordination and compatibility between the codes of each category and the chosen titles. Table 3 shows the results of the safety theme of the knowledge workers in Tehran Municipality. As can be seen, 6 basic themes and 15 organizing themes have been identified.

Also, according to experts' view, several antecedents, moderating factors, and outcomes of the psychological safety of knowledge workers in Tehran Municipality were found. Table 4 includes the results of the thematic analysis for the identified variables.

Finally, after identifying the research variables and determining their relationships, the model of psychological safety of knowledge workers of Tehran Municipality was designed. After the model was designed, 3 experts were consulted about it, and the model was approved by them. Fig. 1 is the research model.

Validation results of the model using the structural equation modeling method

Structural equation modeling based on the

Table 3: Thematic analysis of psychological security of knowledge workers

General themes	Organizer themes	Fundamental themes	Codes
Psychological security of knowledge workers	career dimension	Job design factors	Job meaningfulness, job richness, variety of tasks, job identity, job independence, job attractiveness, and clarity of job roles and tasks.
		Job dynamic factors	Job feedback, the possibility of job learning, job success opportunities, balanced job demands and job resources, job innovation, having the required tools to perform tasks, and job time flexibility.
		Job professional factors	Proper job income, connection of education and occupation, balance of job and personal life, appropriate amount of authority and tasks, low job stress and pressure, job security, and unity of supervision
	Interpersonal dimension	Effective communication factors	Face-to-face communication, continuous and close communication between managers and employees, multiple communication channels, open and free communication between employees, and freedom of speech and democracy.
		Positive interpersonal relationship factors	interpersonal empathy and kindness, organizational citizenship behavior, interpersonal trust, supportive atmosphere of employees and solidarity, and coordination of employees
	Management dimension	leadership style factors	relationship-focused style, transformative attitude, coaching, collaborative management, servant leadership, leader competence, and strategic actions
		Effective human resource management factors	efficient compensation system service, continuous and purposeful training, evaluation of effective performance, meritocracy, talent management, and effective incentive system
	Organizational dimension	Effective organizational structure factors	Horizontal structure of organization, limited organizational bureaucracy, teamwork and group work, flexible and appropriate rules, and efficient organizational processes
		Effective organizational system factors	Administrative transparency, administrative health, respecting the rules, organizational knowledge management, and organizational justice
	Personal dimension	Personality characteristics	Self-efficacy, self-confidence, extroversion, adaptability, emotional stability, and risk-taking
		Attitudinal characteristics	Being Positive minded, being hopeful of the future, self-disclosure, innovation, realism, and ambitiousness
		Skill features	Emotional intelligence skills, effective communication skills, innovative thinking skills, problem-solving skills, decision-making skills, argument ability, the ability to persuade others, and sports and physical activity.
	Spiritual dimension	Ethical	Staying true to moral values, altruism, and philanthropy, respecting others' rights, work conscience, and honesty
		Personal spirituality	Personal virtue, faith in God, righteousness, staying true to the religious rules and forgiveness, and selflessness
		Ethics	Responsibility, accountability, work loyalty, loyalty to the organization, prioritizing organizational interests (over individual interests), and avoiding corruption and conspiring.

partial least squares (PLS) method and Smart PLS software were used to test the conceptual model of the research. To do so, firstly, the adequacy of the sample size was investigated. There are various methods for checking the adequacy of sampling, and in this research, the Kaiser-Meyer-Olkin measure of

Table 4: The results of the thematic analysis of the antecedent, moderating factors, and psychological safety of the knowledge workers in Tehran Municipality

General themes	Organizer themes	Fundamental themes	Codes
Antecedents	Antecedents of knowledge workers' problems	Psychological factors of knowledge workers	Job alienation of knowledge workers, lack of motivation in knowledge workers, burnout of knowledge workers, and high anxiety of knowledge workers
		Functional factors of knowledge workers	Improper use of knowledge workers' capabilities, low participation of knowledge workers in organizational affairs, and low productivity of knowledge workers
	Antecedents of organizational problem	Functional conditions of the organization	The ever-increasing expectations of citizens, continuous environmental changes, gaining organizational legitimacy, growth of the organizational brand, and pressure from external groups
		Environmental pressures	
Moderating factors	features of Tehran Municipality	Features of the organizational environment	Organizational culture, concentration of organizational units, organizational rules and regulations, and diversity of organizational employees
		Features of Organizational Orientation	Organizational values, organizational goals and strategies, the quality of inter-organizational relations and communication with scientific institutions
	Features of knowledge workers	Demographic characteristics	Gender of knowledge workers, the academic degree of knowledge workers, work experience of knowledge workers, and maturity level of knowledge workers
consequences	Organization's Internal consequences	personal consequences	Improvement in performance of knowledge workers, personal growth and improvement of knowledge workers, job satisfaction of knowledge workers, and mental peace of knowledge workers
		Organizational consequences	Realization of organizational efficiency and improvement of organizational effectiveness
	organization's external consequences	Stakeholder consequences	Ensuring the interests of the stockholders and obtaining the satisfaction of the stockholders

sampling adequacy (KMO) and Bartlett's test (t) were used. The output of the KMO and Bartlett test is presented in Table 5.

According to Table 5, since the KMO index value is 0.812 and is over 0.6, and on the other hand, the significance of Bartlett's test is 0.000, the sample size is sufficient. After confirmation of the adequacy of the sample size, reliability and validity should be checked.

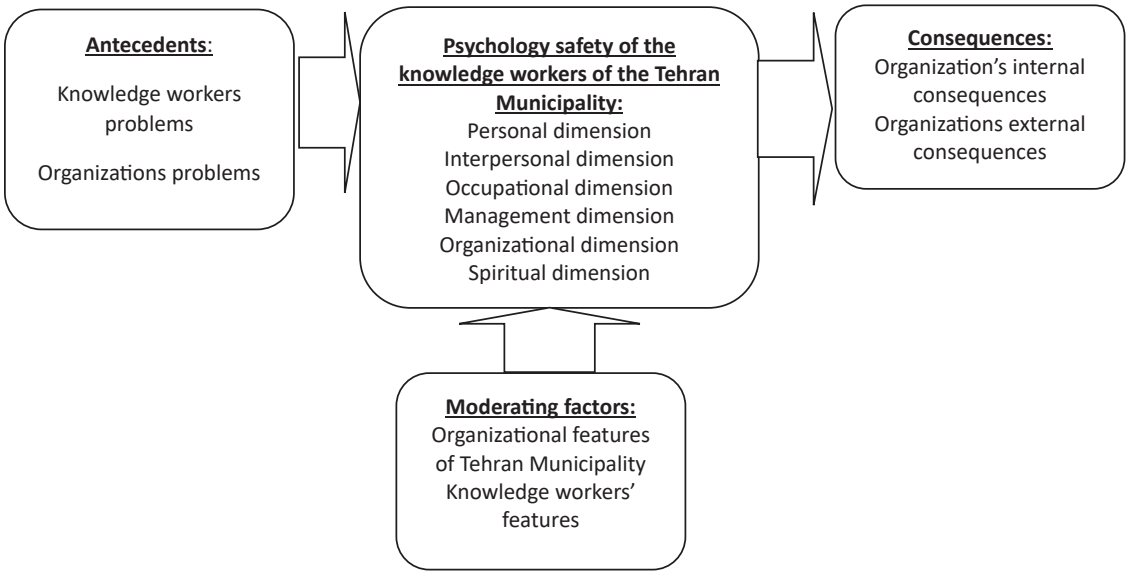

Fig. 1: Psychological safety model of knowledge workers of Tehran Municipality

Table 5: Results of the Calculation of KMO Index and Bartlett's Test

Index	KMO	Bartlett	Sig	Freedom degree	Test result
Value	0.812	52750.40	0.000	35	confirmed

Table 6: Cronbach's Alpha Value, composite reliability, and AVE

variable	Cronbach's Alpha	composite reliability	AVE
Antecedents	0.88	0.90	0.72
Psychological safety	0.83	0.87	0.74
Moderating factors	0.81	0.83	0.67
consequences	0.85	0.88	0.69

To check reliability, Cronbach's alpha and composite reliability methods were used, and the acceptable limit of both values is over 0.7. Cronbach's alpha is a classic measure of reliability and a suitable measure for evaluating internal stability (internal consistency). Also, the composite reliability presented by Verts *et al*. (1974) is a more modern measure of reliability. In the composite reliability, the reliability of the constructs is not calculated in an absolute way but instead according to the correlation of their questions to each other (correlation of questions of a variable in the model). Also, the Average Variance Extracted (AVE) measure was used to test the convergent validity. This measure shows the correlation degree of the structure with its indicators. Fornell and Larker (1981) introduced the AVE criterion to measure convergent validity and stated its critical value as 0.5. The calculated values in Table 6 are all higher than the threshold, and therefore, convergent validity and reliability are confirmed.

Finally, discriminant validity is the third measure of the fit of measurement models. According to the Fornell and Larker (1981) point of view, discriminant validity is acceptable when the average variance extracted for each construct is above the shared variance between that construct and other constructs in the model. According to Table 7, it can be said that the discriminant validity is at an acceptable level.

Table 7: Calculations Related to Divergent Validity

Variable	Antecedents	Safety	moderator	consequences
Antecedents	0.792			
Psychological safety	0.336	0.820		
Moderator factors	0.372	0.245	0.753	
Consequences	0.379	0.360	0.339	0.789

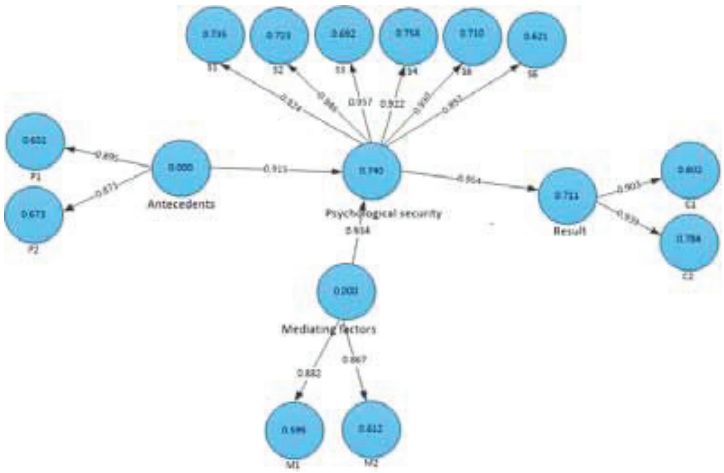

Fig. 2: The structural research model in the significance mode

Because the square root of the average variance extracted ($\sqrt{AVE}$) or all variables are over the correlation of that variable with other variables. Therefore, the discriminant validity of the variables of the questionnaire is confirmed.

Also, unlike the measurement models, the structural part of the model has nothing to do with the questions and obvious variables of the model and only focuses on the hidden variables and their relationships. In this research, the structural model was fitted using the coefficient of determination (R^2), Q^2 criterion, redundancy, and significance coefficients. The most basic criterion for measuring the relationship between structures in structural equation models is the significant numbers of t. If the t-statistic value is not in the range (-1.96 to +1.96), it is significant at the 95% confidence interval. If the t-statistic value is within this range, then the estimated path coefficient is not significant and its hypothesis is rejected. Fig. 2 shows the conceptual model of the research in the significance mode of the coefficients.

Fig. 3 shows the conceptual model of the research estimating standard coefficients. In this figure, the intensity of the influence of the variables on each other is specified. In a structural equation model, each direct effect specifies and shows a relationship between a dependent variable and an independent variable. However, a dependent variable in another direct effect can be an independent variable and vice versa.

Table 8 shows the relationships between the components of the model. As it is presented, all path coefficients are significant, and therefore, the defined relationships in the research model are confirmed.

Also, the coefficient of determination (R^2) is a measure that indicates the level of changes in each of the dependent variables of the model, which is explained by the independent variables (Samimi and Nouri, 2023). It can be said that the R^2 value is only provided for the intrinsic variables of the model, and in the case of extrinsic structures, its value is zero. The higher the value of R^2 related to the intrinsic structures of the model, the model is better fitted (Samimi and Shahriari Moghadam, 2018). Chin (1998) has defined three values of 0.19, 0.33, and 0.67 as the criterion

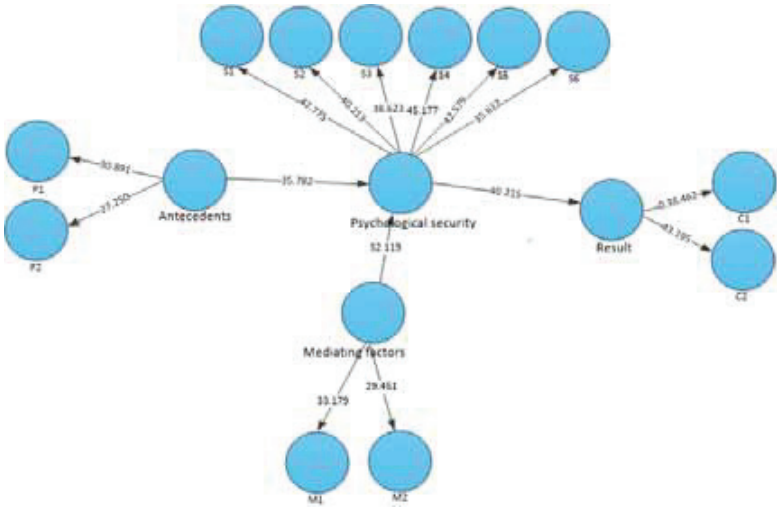

Fig. 3: Structural model of the research in the standard mode

Table 8: Results of the path analysis

Row	Path		Path coefficient	t-Value	result
1	Antecedents	Psychological safety	35.782	0.915	confirmed
2	Moderating factors	Psychological safety	32.119	0.934	Confirmed
3	Psychological safety	Consequences	0.954	0.954	confirmed

value for weak, medium, and strong values of the fit of the structural part of the model by using the coefficient of determination. The calculated R^2 value for the psychological safety of knowledge workers is 0.740, and for the outcomes variable is 0.711, which are suitable values. The Q^2 index was introduced by Stone (1974) and defines the predictive power of the model. According to them, models whose structural part is properly fitted should be able to predict the indicators related to the intrinsic structures of the model. If the value of Q^2 of an intrinsic structure is zero or less, it means that the relationships between other structures in the model and that very intrinsic structure are not well explained, and as a result, the model needs to be modified. Hensler *et al*. (2009) have determined three values of 0.02, 0.15, and 0.35 regarding the intensity of predictive power regarding intrinsic structures. According to them, if in an intrinsic structure, the Q^2 value is close to 0.02, it indicates that the model has weak predictive power. The Q^2 criterion for the variable of psychological safety of knowledge workers is 0.33, and for the outcome variable is 0.30, which are favorable values. Finally, the GOF criterion is also related to the general part of structural equation models; meaning that by this criterion, the researcher can control the fit of the general part after checking the fit of the measurement part and the structural part of the general research model. In a way, the average Communalities show the average communal values of each structure, and Ave R^2 is the intrinsic structure of the model. Three values of 0.01, 0.25, and 0.35 are considered weak, medium, and strong values for GOF, and for this research model, a value of 0.55 was obtained, which indicates the appropriate fit of the research model.

Discussion

In today's world, the contribution of knowledge

workers in organizations is increasing, and due to their special abilities and skills, organizations continue to need more of these employees. Although knowledge workers can make the organization grow and develop, with their extraordinary performance providing them with suitable conditions for activity, especially health and psychological safety, is extremely important. In other words, the nature of knowledge workers' tasks requires them to be calm and focused, and any tension and mental pressure can greatly reduce their performance. Tehran Municipality, as an influential and important organization, is not an exception in this regard, and considering the growing number of knowledge workers and the need of this organization for optimal performance, it is necessary to provide a safe and calm environment for their activities. Therefore, in this research, it was attempted to design a model for the psychological safety of knowledge workers in Tehran Municipality. To do so, semi-structured interview methods with experts and thematic analysis techniques were used. According to the findings, 6 dimensions and 15 components were identified for the variable of psychological safety of the knowledge workers. Also, several antecedents, moderating factors, and consequences were identified, and the research model was formed based on them. The results of structural equation modeling also showed that the designed model is approved and has good fitting power. The value of the coefficient of determination calculated for the variable of psychological safety of knowledge workers is 0.740, and for the outcome variable is 0.711, which are favorable values. Based on research findings, the variable of psychological safety of knowledge workers includes 6 dimensions: individual, interpersonal, occupational, managerial, organizational, and spiritual. From the individual dimension point of view, knowledge workers should develop a set of capabilities, including personality, attitude, and skills, so that they can experience favorable psychological conditions. To reach a favorable point in the field of psychological safety, each person must first start with themselves and create a set of favorable characteristics for themselves. For example, improving problem-solving skills causes knowledge workers to deal with problems more calmly and not lose their mental or psychological focus; by being self-efficient, a person who believes in their ability's experiences higher mental strength and copes with tasks better. Also, the interpersonal dimension is related to the relationships formed in the organization between different people, which can affect the psychological conditions of knowledge workers. The environment of the organization should provide a platform for effective communication between employees in different ways so that people can form relationships with each other in the most optimal way possible. In addition, forming positive relationships between people is very helpful for creating a positive and calm atmosphere and forming synergy. However, it must be accepted that creating a favorable social environment has a great impact on reducing psychological problems since humans are social beings. Plus, the individual and interpersonal dimensions, the job, and related matters are also decisive for knowledge workers. The job is actually something for the development of knowledge workers' capabilities and the flourishing of their talents and competencies. Usually, most of the dissatisfactions of knowledge workers are due to the type and features of their jobs. A job should be challenging both in terms of the features considered for it (job design) and in terms of its dynamism. Also, the professional conditions of the job should be in a way that the employees are freed from issues outside of the job and focused on their tasks. Another dimension is related to management factors that are related to leadership style features and human resources management actions. Organizational leaders create a special environment and conditions with their approaches and attitudes for communicating with employees and keeping the actions of the organization going. For organizations like Tehran Municipality, which have a high number of knowledge workers, leaders should choose a style that matches the characteristics of knowledge workers while having competence. For example, according to the desire of knowledge workers to new problems and their dynamism in their activities, they should have a transformational approach to affairs. Also, the human resource management system should adapt its subsystems according to the conditions of knowledge workers. For example, in the reward system, the share of quantitative criteria for knowledge workers is reduced, and the quality of actions is considered instead. Or, a meritocracy system should be implemented to motivate the knowledge workers. The other identified dimension

is the organizational dimension, which refers to the characteristics of the organization's structure as well as organizational systems. However, knowledge workers work within the framework of organizational structure and conditions, and improper conditions can reduce their performance. The horizontal organizational structure is nice for knowledge workers and minimizes their restrictions in the way of doing their tasks. On the other hand, the systems of the organization should minimize mental and psychological pressure for knowledge workers. For example, injustice in the organization causes knowledge workers not to use their full capabilities and get satisfied with the bare minimum; corruption, as an example, causes lawlessness, discourages, and demotivates knowledge workers. The last dimension is related to spiritual conditions. Spirituality, on its own, is a relaxing factor for people, and paying attention to this helps knowledge workers experience better psychological conditions. Morality and individual spirituality of knowledge workers calm the knowledge workers down and make them experience better conditions by balancing their expectations and better communication with others. Also, following the rules should be noticed as well, which are usually followed by knowledge workers due to their professionalism, and it gives them peace of mind. In general, the results of the research showed that the psychological safety of knowledge workers is a complicated, multifaceted, and dynamic phenomenon that a set of factors must be considered for its better management. In total, the research results showed that the psychological security of academic staff is a complex, multifaceted, and dynamic phenomenon. To achieve this, a set of individuals, interpersonal, occupational, managerial, organizational, and spiritual factors are considered. In other words, at other employee levels, psychological security is more related to individual factors and factors such as wages and job security. However, among academic staff, achieving psychological security depends on multiple and multidimensional factors. Considering these factors can produce valuable results at the individual and organizational levels. Also, the results are compatible with the findings of other previous researchers such as Shirazi and Mesri (2022), Pourahmadi *et al*. (2022), Alavi (222), Golchin *et al*., (2020) Tajabadi and Mohammadimanesh (2020) Sepahvand *et al*. (2018), Golparvar *et al*. (2014), De Oliveira *et al*. (2023), Pacheco *et al*. (2023), Mathibe & Chiniamorindi (2021), Kozi *et al*. (2021) and Akbar *et al*. (2021) and confirms their findings. The current research, while enhancing knowledge and promoting scientific foundations in the field of mental health and psychological security of academic staff in an organizational environment, can be used by the managers of Tehran Municipality for more effective utilization of academic staff. Also, the application of the research results can improve the mental and psychological well-being of academic staff, leading to the enhancement of their job and organizational performance. This, in turn, improves the services provided to citizens and secures the interests of other stakeholders. Finally, it is recommended that future studies investigate the psychological safety of knowledge workers in other types of organizations and compare them with the results of this research. Also, the most important restriction of the research is that the results are related to Tehran Municipality and cannot be generalized to other organizations. To overcome this limitation, future research can be conducted in a broader community.

CONCLUSION

These days, the most valuable asset of an organization is knowledge workers. Knowledge workers use their expertise, knowledge, and experience to create, share, or use their knowledge on the job to help the organization achieve its goals. On the other hand, workplaces are increasingly recognized as important environments where employees' psychological health and safety must be supported and improved. Psychological safety is especially important for academic staff because of their strong need for peace and intellectual concentration in their work. Therefore, this study aimed to design a model of psychological safety for knowledge workers in the Tehran Municipality. This research included two qualitative and quantitative phases, and it is a mixed type of research. In the qualitative phase, semi-structured interview methods with experts and thematic analysis techniques were used to design the research model. Experts of Tehran Municipality who were selected purposefully were interviewed in this phase. In the quantitative phase, the research model was validated by using the structural equation modeling method and Smart PLS software. For this, the managers

and experts of the Tehran municipality were surveyed using a questionnaire. Results showed that individual, interpersonal, occupational, managerial, organizational, and spiritual dimensions are six dimensions, influencing the psychological safety of knowledge workers in organizations. Also, several antecedents, moderating factors, and consequences were identified as well, which were created based on the identified variables of the research model. In addition to the knowledge acquisition, the results can form practical and local knowledge for Tehran municipality managers to provide suitable working conditions for knowledge workers.

Several recommendations are presented based on the research findings:

- It is recommended to redesign the knowledge workers' job positions in Tehran municipality and to create appropriate features in these jobs.
- It is recommended that the managers of Tehran municipality use cooperative and relationship-oriented styles for knowledge workers.
- It is recommended to redesign the compensation system of knowledge workers according to their characteristics.
- It is recommended to strengthen the personality traits of knowledge workers with academic and skill training.
- It is recommended to promote and institutionalize moral values in Tehran Municipality.
- It is recommended to horizatilize the organizational structure of Tehran Municipality and to reduce the level of administrative bureaucracies.
- It is recommended to implement meritocracy and talent management systems in Tehran Municipality.
- It is recommended to promote and encourage positive interpersonal relationships between employees in Tehran Municipality.
- It is recommended to redesign the performance evaluation system based on the characteristics and performance conditions of knowledge workers.

AUTHOR CONTRIBUTIONS

S. Mahdinezhad conducted the research, which involved gathering materials, developing the methodology, collecting and analyzing data, interpreting the findings, and drafting and finalizing the article. M.H. Boochani was responsible for conceptualizing, supervising, orienting, collecting data, and revising the article. A.A. Malekafzali contributed to the research methodology, techniques, and modeling, as well as project management.

ACKNOWLEDGMENT

The authors would like to thank the encouraging words and comments from all the editors and reviewers who have provided valuable contributions to this manuscript.

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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HOW TO CITE THIS ARTICLE

Jafarinian, S.; Vakili, Y.; Hasanpoor, A.; Yalveh, A., (2024). Designing the psychological safety model of knowledge workers in organizations. Int. J. Hum. Capital Urban Manage., 9(3): 429-446.

DOI: 10.22034/IJHCUM.2024.03.05

URL: https://www.ijhcum.net/article_709668.html

Int. J. Hum. Capital Urban Manage., 9(3): 447-456, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Building a business model of enterprise's innovative development based on economic security as an element of urban management

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ARTICLE INFO

Article History:
Received 22 August 2023
Revised 16 December 2023
Accepted 29 January 2024

Keywords:
Business model
Economic security
Enterprise
Innovative development
Urbanization

ABSTRACT

BACKGROUND AND OBJECTIVES: Social and economic processes, which create a combination of capital and intelligence, influence the development of the urbanization process. Urban areas develop together with economic growth. The main factor influencing the growth of the economy is the increase in production, which should be based on quality management through the implementation of a business model for the innovative development of the enterprise in the context of economic security. Thus, the purpose of the research is to define and characterize the components of the business model of an enterprise's innovative development based on economic security and to describe the main practical aspects of its implementation.
METHODS: Using general scientific and special research methods, the theoretical and categorical content was analyzed and specified, namely, the essence of urbanization, innovative activity, innovative development, and business models of the enterprise's innovative development were revealed. The main principles contributing to the effective operation of innovative enterprises were defined.
FINDINGS: It was substantiated that strategic business development provided a business model in which all business processes were identified and analyzed, and development was optimized considering correlations. The main features of the business reflected in the business model were specified. Considering that during the implementation of the innovative development strategy, the business model is aimed at managing the chain of innovative value creation, the basic background for the implementation of the business model was determined. To form a model of innovative development in the context of economic security, the aspects of adaptability of innovative development were investigated. The business model of the enterprise's innovative development in the context of economic security was formed, and its components and their significance were determined. The main practical aspects for implementing the business model of the enterprise's innovative development were highlighted. It was noted that in the conditions of a dynamic market environment, full of dangers and threats, 40% of the success of further implementation should be based on taking into account well-known theoretical and methodological aspects, and 60% should be the ingenuity of the personnel of the enterprise on which the business model is being formed.
CONCLUSION: The business model ensures the transformation of innovative technologies into economic benefits for the company. The practical application of the proposed business model with selected components would contribute to the increase of the enterprise's innovative potential and its development during current activity and in the future.

DOI: 10.22034/IJHCUM.2024.03.06

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
39	3	0

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

Considering the development of urbanization processes in the world and their consequences, it is possible to state the influence of social and economic development on urbanization. Urbanized territories are being developed according to economically reasonable managerial decisions, due to high-quality management in this field. Quality managerial decisions contribute to the development of scientific and technical progress and innovations, which in turn ensures the growth of the economy in the territories that have been urbanized. For instance, the primary strategy for urban centers with weaker resources may be to attract more highly skilled and/or educated workers, and then upgrade the industrial infrastructure of the city (Zhang *et al.,* 2023). Therefore, even though the primary importance of urbanization is reflected in social and demographic processes, there is a need to determine the economic impact and manage economic processes (Gryshchenko *et al.,* 2022). The main component of the economy is production organized by enterprises that create an economic product (Pylypenko *et al.,* 2019). The management of the enterprise, as a component of urban management, should be aimed at its design, which is ensured due to quality management by the new methods, strategic developments, and the introduction of innovations. One of these methods is building a business model for the innovative development of an enterprise (Kuzior *et al.,* 2022, 2023a, 2023b). The impact of economic processes on urbanization and the need for economic management for development were noted in their research papers by the following scientists: Buriachenko (2013) analyzed the factors of urbanization processes and identified distinctive features of urbanization, Blum and Tarun (2007) described urban changes, Kobylynskyi (2021) outlined the factors of the urbanization process and substantiated decisions that contribute to the growth of the economy of urbanized areas, Gonchar (2016) and Pokliatskyi (2016) supplemented the theoretical aspects of urbanization and suggested considering the city as an interdisciplinary object for study. As for the issues of strategic management of enterprise innovative development and the building of business models, it is important to highlight the works carried out by the marketers Johnson *et al.* (2009) who studied approaches to the formation of business models and identified their elements. Osterwalder and Pigneur (2010) researched the business model as an effective tool for business management and company development, Sembay (2023) analyzed innovative business strategies, Yershova and Honcharenko (2022) revealed the essence and types of innovative business models, Otenko (2014) researched the increase and significance of innovative development models for business. We should also mention the progress made in the formation of innovative business models of development by Mykytiuk *et al.* (2015). Iliashenko (2010) in his scientific papers focused on the process of formation and explored the components of business models. Research by Fedulova (2017) was aimed at the formation of innovative development models dealing with the sectoral characteristics of trade. Voloshchuk and Voloshchuk (2020) formed a business model for micro-multinational companies through the implementation of technological digitalization and ensuring the inclusiveness of economic growth (Bezrukova *et al.,* 2022). The process of solving the problems in the field of ensuring economic security for enterprises that face complex difficulties was scientifically beneficial for Shumilo *et al.* (2020) who proposed an assessment of the effectiveness of managing economic security in supply chains, taking into account innovative aspects. Alkema *et al.* (2015) and Litvin *et al.* (2021) have studied the challenges of economic security in innovative enterprises. Scientists consider concepts, and methods and build the models for management of innovative activity (Babenko *et al.,* 2022), but this research is not enough when it is said about the formation of business models of innovative development in the context of economic security and the definition of their components (Karpenko *et al.,* 2019; Zomchak and Nehrey, 2022). Controversial questions arise regarding the understanding of the structured approach and the formation of the number of business model elements (Solokha *et al.,* 2019) There are also a few research papers on the relationship between economic activity and urbanization processes, that make this topic relevant (Kolodiziev *et al.,* 2018; 2022). The purpose of the current study is to deepen and expand the theoretical aspects concerning the essence of the enterprise's innovative development and ways of building a business model (Nehrey and Hnot, 2019), supplementing

its components taking into consideration ensuring economic security and the possibility of adapting this model an urban environment as the element of urban management. To achieve these objectives, the research survey was conducted in the urban area of Kharkiv, Ukraine in 2023. Based on the understanding of urban processes it is expected to provide the idea that the implementation of business models into the activity of enterprise contributes to its innovative development. The process of forming business models of innovative development and the selection of their main components is important, which will promote the achievement of the strategic goals of enterprises.

MATERIALS AND METHODS

The theoretical and methodological basis that has been used during the research process are points of the concept of innovative development, business model creation, economic security, and urbanization development. The theoretical and categorical content was analyzed and specified following the general scientific and special research methods: logical generalization, analysis, comparison, and synthesis. The structure of the business model of innovative development has been developed, and its components have been identified using the methods of structuring and synthesis.

RESULTS AND DISCUSSION

Urbanization is a very complex process, and it cannot be interpreted only as the growth of cities and the increase in the quantity of urban population. This phenomenon should be understood as "a new stage of social development, which is characterized by the concentration of economic, demographic, and political potential, which provides an opportunity to centralize and control significant amounts of financial resources, create new technologies, new types of services, and carry out innovative activity" (Buriachenko, 2013). The network of metropolises has always been the core of the national economy because these settlements are centers of migration attraction and a source of economic, financial, and intellectual activity. Capital and intelligence – this is the exact combination that is most necessary for the development of cities and the country as a whole (Poklyatskyi, 2016). The main economic factors of urbanization are production and industry, they are located in cities, consumer- and information-oriented, interact with other enterprises, and concentrate significant human resources, due to a large territory (Biriukov, 2013; Sergienko, 2019). As a result of large cities' evolution, industry develops and contributes to the increase of economic activity and is a financial factor of urbanization. A large city provides production and concentration of both production and financial resources, development of marketing and information technologies, and innovative activities. Innovative development of the enterprise is one of the main conditions for its economic growth, during which innovative reorganization contributes to ensuring indicators of economic development, growth of economic potential, leadership in competition, and solving social problems. However, the changes that occur in the global space of the enterprise's functioning constantly affect the direction of changes in the development and implementation of innovations, and the search for new tools of strategic development (Otenko, 2014). The business model of an enterprise's innovative development is such a relevant tool. Innovative development should take place in such conditions that prevent threats to the enterprise's economic security, and it determines the building of the enterprise's business model in the context of economic security. Innovative development is essential for the success of a modern enterprise. The complexity and dynamism of the external business environment, crisis phenomena, and increase in the intensity of competition require enterprises to adopt an appropriate model of behavior through the implementation of innovative changes in products and services, technologies, and key business processes (Savytska *et al.*, 2022; 2023). The innovative activity of the enterprise covers its entire life cycle and consists of the implementation of innovations in both production and non-production areas. Among scientists, who reveal the essence of innovative activity, a process approach is often used, in which the following is distinguished: marketing research of markets from consumer's and supplier's points of view; evaluation based on the formed information base of product properties on the specified market; solving problems addressing the concerns of an innovative project financing (Malyarets *et al.*, 2021). In general, the innovation process can be considered as a set of actions aimed at creating an innovation and introducing it into the practical activities of

the enterprise, which contributes to its innovative development. Innovative development is considered in two aspects: subject and technological or oriented to scientific result, in which it is considered as the outcome of scientific only or scientific and technical activity; functional, in which it is associated with the functions of creation, implementation, dissemination of innovations, implementation of innovative projects (Mykytiuk, 2015). Therefore, innovative development is a process of economy that is based on the continuous search and use of new ways and areas of realizing the potential of enterprises under the changing conditions of the external environment within the framework of the chosen mission and accepted activity motivation and is connected with the modification of existing and the formation of new market channels (Iliashenko, 2010). When studying the experience of successful companies in the development and use of innovations, the main principles that contribute to the effective operation of innovative enterprises were highlighted:

– *Innovation is considered a discipline* that provides understanding to the company's personnel to generate, define, and implement ideas in practical activity.

– *A comprehensive consideration of innovations*, which mainly consists of comprehensively covering the company's activity: new products, services, processes, strategies, business models, sales channels, and markets.

– *Innovation as a tool for finding new opportunities.*

– *Involvement of all enterprise personnel in innovations.*

– *The orientation of innovation on the consumer*, which means the need to encourage the client to express an opinion and later take it into account during the development of new concepts.

It should be noted that the innovative development of the enterprise is a process aimed at regular changes in its state, where the source of innovative potential is precisely the set of innovations that provide new, high-quality opportunities for the enterprise's activity on the market as a result of new ideas, solutions, inventions, etc. The enterprises reveal their difference in creating innovations that are part of the business, while in other enterprises, innovations are part of the general activity. The orientation of the enterprise to the innovative type of development requires constant changes in all its elements (strategy, structure, processes, products, personnel). The relationship between strategic and innovative activities is becoming closer in the conditions of intensifying competition, the transition from mass to specific order production, increasing the role of management automation, reducing the duration of the development and introduction of new products, and expanding corporatization. That is why the toolkit for managing the enterprise's innovative development is based on the methodology of strategic management, namely, conceptualization, business modeling, and strategic planning (Mainka, 2020). The formation of a business model for the enterprise's innovative development, based on innovative capabilities, principles of the theoretical base, new approaches, conceptual ideas, and methodological tools, is effective among the existing ways of realizing the innovative potential of the enterprise. The business model allows for a fairly complete description of the logic and methods of conducting business, including its organizational, functional, and technological structure, interaction with suppliers and consumers, the flow of money, financial efficiency, etc. The purpose of developing a business model is not a simple description of the business, but the identification and analysis of all business processes, their optimization, and development taking into account all interrelationships (Fedulova, 2017). The business model of the enterprise is the most important concept that corresponds to the business development strategy. It can be claimed that the business model is a concept based on which structuring and transfer of strategy to the operational level takes place, which means the probability of realizing the company's strategic goals. A business model is a simplified model of a complex object (business system), which reflects the logic of the entire enterprise operation. It characterizes the main business objects, their interrelation, and the system of relationships with the external environment. The business model shows the most essential business peculiarities, shown in Fig. 1.

In the context of the implementation of the innovative development strategy, the business model has to be aimed at managing the chain of innovative value creation. From this point of view, certain prerequisites for the implementation of business models are worth considering (Fedulova, 2017), they are:

– the need to make innovations more efficient in terms of spending money and time, as well as manage risks by including them directly in the business model;

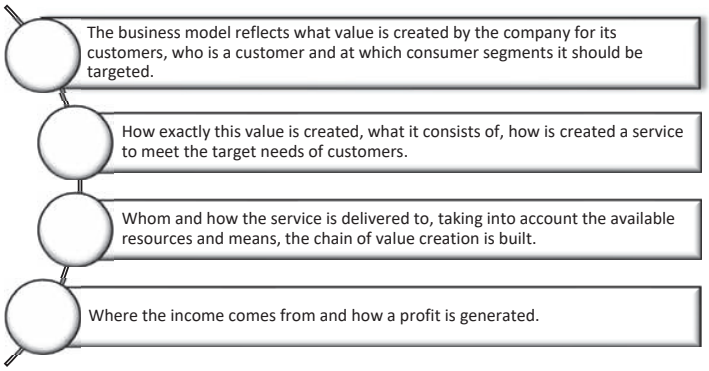

Fig. 1: The main features of the business reflected in the business model

– opportunities for small innovative companies to make money from open innovations (for example, license programs that are not associated with restrictions on further modification, but with the preservation of information about the original authorship and the changes made);

– opportunities for large innovative companies to earn from innovative programs (when large companies purchase licenses for products manufacturing from small companies and take them to the market under their brand);

– opportunities for large innovative companies to earn on the intellectual property of those business directions from which it originated (as an example, to receive a royalty from companies that produce discontinued products under the brand name of a large company);

– opportunities for large innovative companies to make money from open innovations due to the formation of standards and even business trends in their field.

During the building of the business model, firstly, the needs of consumers are determined and evaluated, it is determined where the high-profit zone is located, and how it can be obtained in the maximum volume; the direction of activity is determined, as well as how to get a high market share according to the chosen direction; a system of methods of organization, protection and support of the high-profit zone of innovatively active enterprises is being built (Voloshchuk and Voloshchuk, 2020). Considering the dynamic development and trends of business intellectualization; the growth of the role of the innovative component in increasing the enterprise competitiveness; the comprehensive impact of information flows; the development of electronic business; the wide use of economic and mathematical calculations, as well as the concept of business modeling, it is considered that today it is necessary to talk about the enterprise "business model" as a generalizing concept that covers all aspects of company management (Mykytiuk *et al.,* 2015). So, the business model can be interpreted as a set of components with homogeneous elements that distinguish the logic of the enterprise's functioning from the logic of competitors. In the conditions of transformational changes in the modern environment, the building of a business model of innovative development should also be innovative. It means that it must be flexible, quickly respond to all changes in the external environment, and adjust the enterprise business processes to the conditions in the market where the enterprise operates. Under the specified conditions of the enterprise operation, in conditions of constant changes and uncertainty, it is obligatory to control and ensure the economic security of the enterprise. Therefore, it is always a good idea to take into account this aspect during the building of the innovative development business model. Effective functioning should be ensured only in conditions of a sufficient level of economic security for each business process and in general the enterprise as a whole (Chorna *et al.,* 2019). It should be noted that innovations have a dualistic nature, both technological and economic, which generally indicates their adaptability. Firstly, there should be chosen an innovative idea that adapts to the goals of the enterprise, the enterprise itself adapts to the implementation of the innovation, and then the innovative product should adapt to the market requirements, along with this, innovative

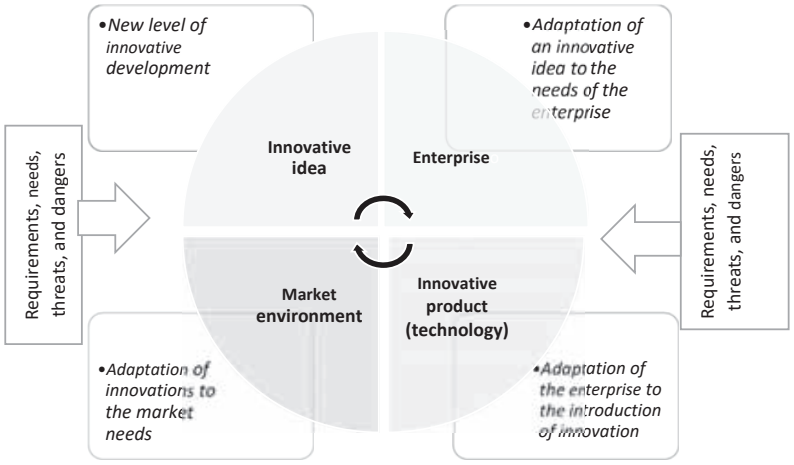

Fig. 2: Adaptability of innovative development (developed by the author by Alkema *et al.*(2015))

products contribute to the development of the market (Fig. 2).

During the adaptation of an innovation, threats to economic security (of its innovative component) arise, which can be concentrated into three groups (Alkema *et al.,* 2015):

– technological threats – risks associated with the probability of obtaining final scientific results, timeliness, safety, and perspective of the work carried out and the results obtained, compliance with modern technological equipment before the acceptance and launch of the received developments and samples into industrial production;

– market threats – risks related to the readiness of the market environment that the enterprise with an innovative development will enter before adopting this innovation, the presence of hidden demand or market expectations, competitors' developments, etc.;

– project threats – risks directly related to the planning, development, and implementation of an innovative project, its cost, term, quality of execution, and value of the obtained result.

Taking into account all mentioned above, guaranteeing and ensuring economic security should be an obligatory component of the business model of the enterprise's innovative development.

Discussion

Summarizing the results of research provided by scientists on the understanding of the elements of an enterprise's business model, six key components have been identified that combine homogeneous elements to build a business model for the innovative development of an enterprise in the context of its economic security (Fig. 3).

Will consider more details about each component of the business model of enterprise innovative development in the context of economic security. The first component determines the value of the business, and its main directions, and within its framework a business portfolio is built. New business ideas for the innovative development of the enterprise are determined. The directions of innovative activity are determined following the priority directions of social and economic needs of society, which are determined at the legislative level. Determination of innovative activities types and innovations to be implemented, tasks for performers of innovative development of business processes. Innovative development strategies are developed based on the results of the analysis, and strategic orientations are determined, which are represented by various programs and projects. For the enterprise that implements innovative projects, a system of economic security must be built, where the identification of threats and dangers to the enterprise's economic security is significant. The second component includes the formation of consumer value offered by the enterprise based on its innovative products and services, the identification of suppliers and consumers, and the building of relationships between them. This component also includes shaping the value chain and creating a new vision for profit and revenue generation.

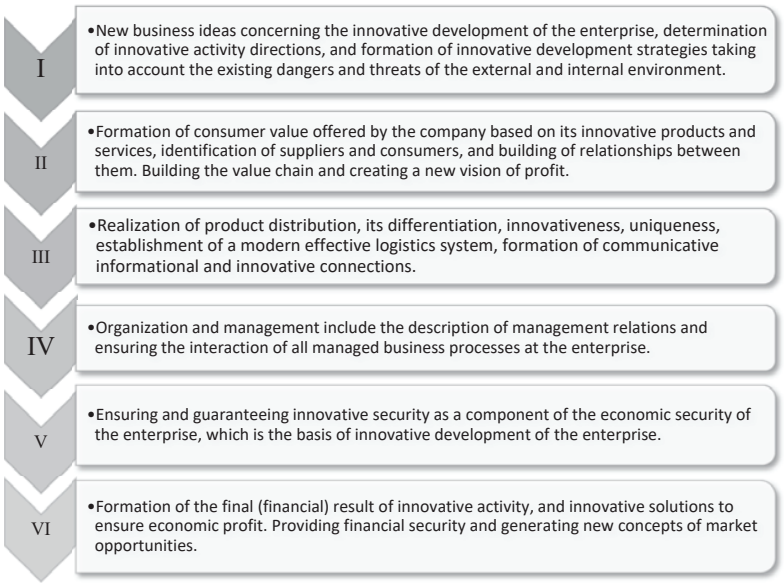

Fig. 3: Components of the business model of innovative enterprise development in the context of economic security

The third component of the business model includes the realization and distribution of the product, and its differentiation which involves positioning and branding considering the functional properties, purpose of the product, its cost, other related services, its innovativeness, main competitive advantages, uniqueness of its offer and image (Voloshchuk and Voloshchuk, 2020). This component includes the creation of communication, information, and innovation channels and ensuring their interaction. The organization and management component includes a description of management relationships and ensuring the interaction of all managed business processes at the enterprise. This component includes ensuring and guaranteeing the enterprise's economic security and, separately, innovation security, which is the basis of the enterprise's innovative development. The component includes the formation of the final (financial) result of innovative activity, and the adoption of innovative decisions to ensure economic profit. Providing financial security and generating new concepts of market opportunities. Concerning all mentioned above, it can be claimed that innovation should be considered according to the directions determined by the key elements of the business model used within the company. Among the key elements, the following should be specially highlighted (Mykytiuk *et al.,* 2015): consumer segments, types of relationships with them; the value that the enterprise offers based on its products and services; supply channels of this asset, processes of key activities, as well as key partners; an innovative component of the enterprise's economic security, assets that the company uses to create value; the company's financial model, which determines the structure of its costs and money flows. It should be noted that during the development and implementation of a new business model, changes in its key elements occur. The new business model changes the rules of the game in the market and generates significant importance both for the enterprise itself and for consumers. Understanding the elements/components of the business model of innovative development contributes to opportunities for a structural view that explains the strengths and weaknesses of the business. To improve innovative activity, based on structural analysis, it is possible to determine priority areas that need support, as well as improve the enterprise's innovative activity and determination of ways for its development based on the visualization of all aspects of economic activity. Also, it allows for providing the foreseen results of innovative activity and dynamic business growth based on a correctly selected business model. As for the main practical aspects of the implementation of the business model of the enterprise's innovative development, the

following should be highlighted. Identifying the specific features for building an innovative business model is based on the understanding of how the company profits from market opportunities. It is important to integrate the elements of the business model into the existing management system at the enterprise, the system of plans, reports, and meetings. Furthermore, it is essential to consider the impact of the quality of the innovative business model on enterprise management. Thus, building a high-quality business model should be based on modern development trends, not on accepted practice. Globalization and accessibility to new business schemes are generating new methods of profiting from new market opportunities that are constantly emerging. The management process at the enterprise must be innovative. For the implementation of innovative proposals, it is necessary to have a means of simple and effective visualization of business ideas. The business model of innovative development allows you to structure the intellectual activity of generating business ideas and make it accessible to all personnel and interested parties. Employees can engage in business innovation during the working period. The conceptual apparatus of business modeling allows users to concentrate on the search for innovative business concepts. The building of a business model is the basis of the company's activity. Therefore, business owners and managers to improve and gain a deeper understanding of the development strategy should directly participate in its creation as well as entrepreneurs who create start-ups and want to present a business model to investors and team members. Managers and leaders responsible for the development of the company should systematize the existing situation and present plans for the renewal of the company. Consultants, business trainers, and specialists in organizational development should develop a business model as part of a strategy for clients to structure work. The business model ensures the transformation of innovative technologies into economic benefits for the company. Its application in the practical activity of the enterprise will contribute to the increase in the innovative potential of the enterprise and its development in the current activity and the future. The prospect of further research in this direction is the development of ways to implement the proposed business model of innovative development, and enterprises in the context of economic security during the formation of the city's development strategy.

CONCLUSION

As a result of the research, the purpose of which was to supplement the theoretical and methodological aspects of building a business model for the innovative development of an enterprise, taking into account economic security, a business model was formed. Its main components are identified, which determine the directions of innovative activity of enterprises, contribute to innovative development, and correct the process of adapting the model in an urban environment. The business model of innovative development is an element of strategic management, thanks to which innovative technologies are transformed into economic benefits for the company and high consumer value. In the conditions of urbanization and a dynamic market environment, full of dangers and threats, the business model of enterprise's innovative development, considering economic security, is a modern tool of management aimed at the implementation of the enterprise's development strategy and the element of urban management. The need for innovative development of the company contributes to its successful functioning in the market, and the formation and implementation of innovative development business models is an element of strategic management. Due to the business model, innovative technologies turn into economic benefits for the company and high consumer value for consumers. Introducing the components of the business model of an enterprise's innovative development based on economic security into the company managerial process will contribute to the achievement of business success. The main practical aspects of implementing the business model and the proposed list of persons who should participate in the process of its formation can be considered as a management tool in practical activity.

AUTHOR CONTRIBUTIONS

V. Babenko designed the methodology. O. Shumilo performed the literature review, and experimental design, analysed and interpreted the data, prepared the manuscript text and manuscript edition. V. Babenko and O. Maslak performed the experiments and literature review, compiled the data, and manuscript preparation. O. Davydova and L. Sokolova helped in the literature review and manuscript preparation. I. Volovelska and V. Yefanov performed some of the remained experiments.

ACKNOWLEDGEMENT

The authors of the article, namely Dr. Vitalina Babenko, express great gratitude to the Institute of International Education's Scholar Rescue Fund (IIE-SRF) for the help and support that the fund provides to scientists who find themselves in a dangerous situation. Thanks to IIE-SRF, Dr. Babenko received full assistance and the opportunity to continue the scientific research, in particular, to publish this article.

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.

OPEN ACCESS

PUBLISHER'S NOTE

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HOW TO CITE THIS ARTICLE

Babenko, V.; Shumilo, O.; Davydova O.; Sokolova, L.; Volovelska, I.; Yefanav, V.; Maslak, O., (2024). Building a business model of enterprise's innovative development based on economic security as an element of urban management. Int. J. Hum. Capital Urban Manage., 9(3): 447-456.

DOI: 10.22034/IJHCUM.2024.03.06

URL: https://www.ijhcum.net/article_710505.html

Int. J. Hum. Capital Urban Manage., 9(3): 457-472, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

The quiddity of familiarity concept (taarof concept) and reasons weakening it in contemporary Iranian cities

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ARTICLE INFO

Article History:
Received 01 October 2023
Revised 17 January 2024
Accepted 10 March 2024

Keywords:
Concept of familiarity
Islamic city
Land reforms
Land-use planning
Neighborhood

ABSTRACT

BACKGROUND AND OBJECTIVES: The concept of familiarity (taarof) is one underlying concept of an Islamic city, which has received less attention. Adherence to this concept that is adopted from Quranic teachings has a considerable influence on the neighboring or neighborhood concept. However, the evolutions in the contemporary Iranian community have left this concept in serious challenges over recent decades, causing underlying developments in the concept of neighborhood. This study investigates the advent of challenges threatening the familiarity concept in terms of evolutions in the contemporary history of Iran, particularly in terms of the contemporary political economy of Iran to find how these changes and developments in the political economy have threatened and weakened the concept of familiarity in contemporary Iranian city.
METHODS: This study is based on the library-documentary method in terms of data collection, and is based on logical reason in terms of data analysis and judgment. Logical reasoning encompasses a wide spectrum from computer programs and formulas to cultural discourses and theses, and this study comprises the cultural discourse extreme of this spectrum.
FINDINGS: According to the results of this study, some political economy developments in the contemporary history of Iran, including land reforms, the municipality's income generation system, injecting the oil revenue into metropolises, and lack of adherence to principles of land-use planning have led to the advent of the concept of displacement (or relocation) and permanent population changes and migration from rural to urban areas or inside the urban areas (especially in metropolises). Subsequently, such severe population changes have resulted in a weakened concept of familiarity threatening the neighborhood concept.
CONCLUSION: The most important requirement for deepening neighboring relationships and stabilizing the concept of familiarity in the contemporary Iranian city is revising macro-policies of political economy to stabilize the citizens' settlement in the place they are living by adopting appropriate policies, so this stabilization would lead to longer neighboring relations and deepen the familiarity and familiarity between neighbors. In this case, the issue of displacement can be somewhat solved, and the social harms caused by the weak concept of familiarity can be eliminated in contemporary Iranian cities.

DOI: 10.22034/IJHCUM.2024.03.07

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
39	4	3

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

After Western communities transitioned from tradition to modernity, the new system, such as the feudalist system created necessary institutes for its survival or coordinated the traditional social institutes by applying some changes in some cases (Giddens, 2013). Moreover, as one of the institutes forming the traditional city, the concept of the neighborhood was changed due to the transition from tradition to modernity and the advent of capitalism. As an introduction to modernity, the Industrial Revolution required workers to make themselves ready for jobs anywhere leaving their native lands and residence places, which threatened neighborhood relationships preventing them from being deepened. Durkheim (2013) considers labor division as the driving force for achieving a developed community. When a community becomes larger, the previous reconciliation factor that is collective consciousness cannot alone create community connection while individual responsibility becomes meaningful in response to actions because family and group relationships are weaker and the person is more free, responsible, and autonomous to make decisions. In modern communities, social action characteristics have been institutionalized at a high level of individuality (shahesmaili Nezhad khorasani and Azadarmaki, 2020). Giddens (2013) believes that modernity has changed some concepts, such as time and place through labor division and formulation of new organizations and institutions. These two concepts were matched in premodern communities meaning that social life dimensions were in the framework of local activities depending on the time and place. Modernity advent allowed non-attendance interactions by strengthening the relationships between absent individuals. After the emergence of modernity, the time calendar was separated from the geographical location, and the whole world found a single criterion. Emptying the time was a prerequisite for emptying the place. After modernity, the place has been separated from location. Time-place separation is the prerequisite for the occurrence of displacement processes leading to the separation of social relationships from the local interaction environments and renovation of them in infinite time-place structures and zones (shahesmaili Nezhad khorasani and Azadarmaki, 2020), and this displacement phenomenon is the factor for transiting from tradition to new era. Displacement or relocation threatens the concept of neighborhood and weakens the familiarity among occupants of habitats (including metropolises and cities) due to population displacements. This familiarity is defined with the term "*Taroſ*" in the Holy Quran, which implies the concept of familiarity "*Taaroſ*" (Surah Al-Hujurat, Verse 13). "*Taaroſ*" is rooted in "*Araſ*" which means familiarity with individuals and familiarity with people. This study examines the effects of the displacement phenomenon in the frame of migrations and population relocations on the concept of familiarity in the contemporary Iranian city and aims to answer the main question of the study to find reasons for weakening familiarity in the contemporary Iranian city. This question asks "What are the reasons for weakening the familiarity and subsequently the concept of neighborhood in Iranian cities in terms of the developments that occurred in the political economy of Iran?" According to the mentioned points, this study focuses on two main subjects; the first one is the concept of familiarity and the concepts associated with it, including neighborhoods in Islamic cities, and another one includes factors weakening this concept in the contemporary urban-planning system of Iran. Therefore, the research background has two parts. Few studies have been conducted on the first part (related to the concept of familiarity and concepts associated with it) because urban planning literature is a novel field with a minor background. Raeesi and Mohammad Ali Nezhad, (2021) conducted a study titled "Explanation of the scale and general model of the neighborhood consisting of neighborhood units from an Islamic perspective" and investigated the necessity of the neighborhood scale limitation (in terms are area and population). They explained that when the area and population of the neighborhood exceed a certain limit then the concept of neighborhood and subsequently, the concept of familiarity, which are the most important concepts emphasized in Islamic teachings become weak. Keshvari (2016) explains that if the physical structure and architecture of the neighborhood ensure maximum familiarity among neighbors, the concept of familiarity would be strengthened, providing many advantages, such as increased security, decreased crime, and improved human relationships. Consideration of the relationships created in traditional neighborhoods within Western contemporary urban planning has led to the advent

Table 1: Comparison between Western and Islamic neighborhood units

Component's type	Component's name	Islamic neighborhood unit	Western neighborhood unit
Functional	The main pillar of the neighborhood unit	Mosque	School
Functional	Population	Between 1000-1500 people	Around 5000 people
Physical	Neighborhood unit radius	Varying (based on the size of residential blocks), while observing the maximum 500m radius	Maximum 800m
Physical	Area	A total of 40 blocks from 4 directions, up, down, left, and right (160 blocks in total) with mosque orientation at the center of the neighborhood unit and an approximate 20-hectare area totally	Around 160 acres (each acre almost equals 4000m^2) with school orientation at the center of neighborhood unit and an approximate 64-hectare area totally
Historical	Background and history	More than 14 centuries and returning to early Islam (cited to hadiths narrated by Imams)	Around one century and returning to the pattern proposed by Clarence Perry in 1923
Semantic	The main nature of neighborhood unit	Social-cultural	Physical-functional

of some patterns, such as Clarence Perry's pattern (Rohe, 2009). According to this pattern, residents used certain social services jointly within the single neighborhood unit, whose population and size were defined based on the educational use of elementary school (Eslami and Aminzadeh, 2013). Table 1 presents the comparison between two concepts of the Western neighborhood unit (based on Clarence Perry's pattern) and the Islamic neighborhood unit (based on the religious documents).

According to Table 1, despite some differences, the concept of neighborhood and particularly the neighborhood unit have been considered in both Islamic and Western urban planning. The reason is that architectural and urban-planning structures weakening the familiarity among citizens especially at the neighborhood scale would result in social divergences, and subsequently in social capital erosion (Mohammadi and Musavi Moqaddam, 2022). In contemporary urban planning also concentrated social correlations have been replaced with various networks of transient social relationships due to the changed physical structure of neighborhoods and centralized neighborhood divisions to a set of noncentralized layers and extensive developments in the settlement system of cities (Eslami and Aminzadeh, 2013). In cities that are heterogeneous, diverse, and multicultural, however, a neighborhood is a place for urban subcultures (Rapoport, 2001). There are other studies indicating the relationship between architecture and urban planning on the one hand, and social relationships and interactions on the other hand (Mendes *et al*. 2017; Williams, 2005). According to the results obtained from these studies, the architectural structure of a place is not independent of the lifestyle of the users and social structure (Aydın and Sıramkaya, 2014). This is highly critical in the Islamic culture because the Islamic teachings emphasize the quality of the social structure of the neighborhood and city with particular concentration on the mosques (Araki, 2021). Accordingly, the Islamic city must be directed in a way that familiarity becomes an alternative for some concepts, such as pride to improve intercultural communications (Ghamami and Islami Tanha, 2022). In the second part of the study (effective factors in weakening the concept of familiarity), few studies can be found about the factors affecting the concept of familiarity in contemporary Iranian cities since this concept is a novel and innovative topic. However, few studies have examined some components, such as weakening the concept of neighborhood (that is associated with the concept of familiarity) in contemporary Iranian cities through an indirect approach. Shahesmaili Nezhad Khorasani and Azadarmaki (2020) have investigated the displacement issue in the modern Iranian family considering some social developments during Qajar and Pahlavi periods. They explain the process through, which this topic has led to migration to contemporary Iranian cities. Mahdavi

Table 2: A brief comparison between some relevant studies and extant studies and an explanation of the innovative aspect of this study

The main subject of research	Sample	Main themes	Novelty aspect of this study
What is the concept of familiarity?	Raeesi and Ali Nezhad (2021); Keshvari (2016)	The nexus between the area and the population of the neighborhood with the concept of familiarity	Generalizing the concept of familiarity to the contemporary cities of Iran and addressing why the concept of familiarity has been weakened in these cities
Factors affecting the weakening concept of familiarity	Shahesmaili Nezhad Khorasani and Azadarmaki (2020); Imani Shamlou *et al*. (2016); Abadian (2018)	The role of some factors, such as oil revenues, land reforms, and other contemporary economic political developments on the population displacements and its social consequences	A holistic and extra-sectoral view on the effective factors in weakening the concept of familiarity in contemporary Iranian city

Vafa *et al*. (2009) have explained the effect of some factors, including the oil-depending economy on the spatial developments of Iran, and subsequently the population displacements and severe formation of social classes in the Capital City by reviewing the role of political economy in the spatial structure of Tehran and its surrounding environment. Hatami Nezhad and Abdi (2007) have explained the effect of political economy on urban spaces and the incidence of some issues, such as the entrance of numerous migrant workers to urban areas. Imani Shamlou *et al*. (2016) have analyzed the spatial developments in the Tehran Metropolis but also confirmed the role of the oil economy on the spatial divergence, social and class gap, and separation between the rich and the poor in the capital. Abadian (2018) examined land reforms the effects of this project on the migration of villagers to Tehran, and the social consequence of this phenomenon. Table 2 reports the difference and novelty aspects of the present study compared to the other cited studies in the literature review.

Although the literature reviews have all addressed the population displacements (particularly from villages to contemporary metropolises of Iran), the distinctive difference between them and the extant study can be seen in two points: firstly, the mentioned studies have considered just a certain aspect of the migration issue without having a comprehensive view on the factors affecting the extensive displacements and migrations to contemporary metropolises of Iran. Secondly, none of the mentioned studies have concentrated on the effect of these numerous migrations on the concept of familiarity and weakening it. These two issues constitute the innovation aspect of the present study.

The current study has been carried out in Qom in 2023.

MATERIALS AND METHODS

This study is based on the documentary-library study in terms of data collection and is based on logical reasoning in terms of data analysis and judgment. Although the logical reasoning technique consists of a wide spectrum from computer programs and formulas to cultural discourses and theses (Groat and Wang, 2013), the nature of the logical reasoning method in this research includes the cultural-discourse extreme of this spectrum, while formulas and models are eliminated in this study. It is worth noting that theses in this spectrum comprise systems that have persuasive potential relying on a worldview and logical expression of these concepts, and using theoretical clarity. These systems present their claims based on excellent logic by using discourse language and regular analysis and explanation. One of the most important features of the logical reasoning method is that it is more comprehensive than other research methods because every conceptual framework must reach a form of logical reasoning. In addition, if the reasoning framework is followed correctly, it can hardly be rejected, which is another feature and advantage of the logical reasoning method. But at the same time, care must be taken that logical reasoning does not fall short in describing a wide range of facts. In terms of methodology in all types of studies, dependability criteria are important, but this significant point depends on the paradigm in which, the research is carried out because the

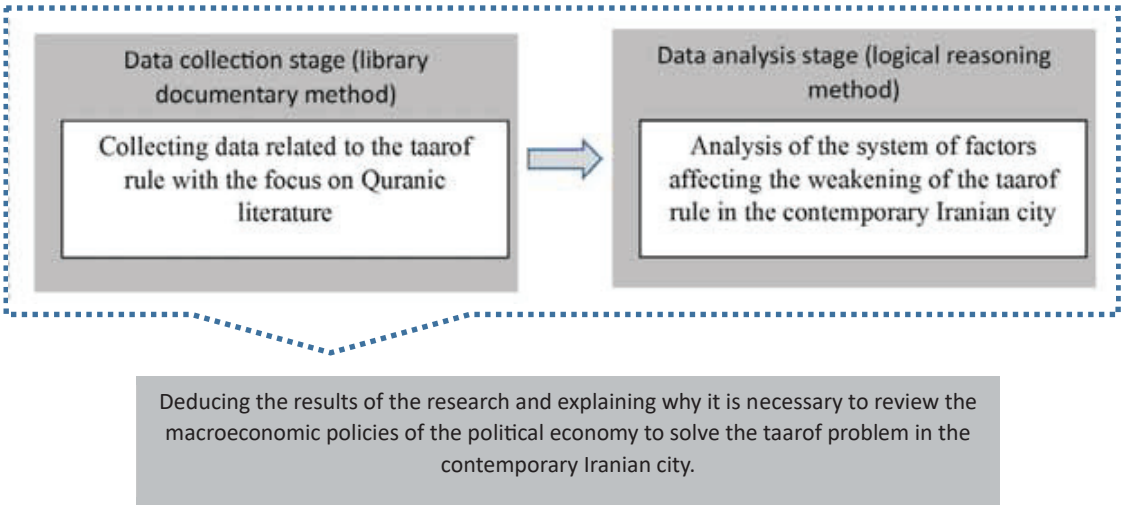

Fig. 1: The general path of the current research and the research method appropriate to each stage of the research

various paradigms used in research provide various criteria for validation and dependability of a certain research (Raeesi, 2016). For instance, the common criteria called validity and reliability are used to assess the quality of knowledge in the positivism paradigm; however, this study is not of this kind of paradigm. Hence, the dependability of this research that has used a logical reasoning technique must be determined. As mentioned before, this study belongs to the logical cultural-discourse systems in which, confirmation of logicality does not mean in the cultural setting of the same system. In such studies, "persuasiveness" can interpret the concept of "dependability" (Groat and Wang, 2013), which this case is rooted in its inner logical integrity. Ultimately, it can be stated that in such studies that are not dependent on the metrics of positivist research, the knowledge quality criterion includes confirmability and transferability (Mohammadpour, 2011). Fig. 1 depicts the general process of the present study and the research method related to its various steps.

RESULTS AND DISCUSSION

The quiddity of the concept of familiarity (taarof)

In the Islamic city, the concept of taarof can have different scales (including local scale, urban scale, national scale, international scale, etc.), each of which has its requirements; But since the single cell in the structure of the Islamic city is the neighborhood, and considering that the Islamic city is neighborhood-oriented, this research is focused on the concept of taarof at the local scale, because in the neighborhood (as the basic cell of the Islamic city) if the concept of taarof is not respected, then it will not be achieved in other scales. Since the interpretation of the familiar concept depends on describing the neighborhood boundary at the neighborhood scale, the optimal boundary of the neighborhood must be determined based on the Islamic perspective. The reason is that when the size of the neighborhood exceeds a certain area, getting to know neighbors and familiar concepts becomes difficult in that neighborhood. Mosque has a special position in Islamic city (Amirabadi Farahani and Raeesi, 2022), so that Islamic city is a mosque-oriented city, and each city consists of many neighborhoods with a center at its center and its surrounding context (Raeesi, 2018). Many historical documents confirm this claim; for instance, it has been stated that when Madinah Al-Nabi was developed, the Prophet Mohammad determined 10 Gaz (a unit for length) for the width of the mosque's road and then ordered to consider 7 Gaz for other roads (Amili, 2012). It has been also narrated in another document that he first outlined the location of the mosque and then projected houses around it (Raeesi, 2018). According to these documents, the

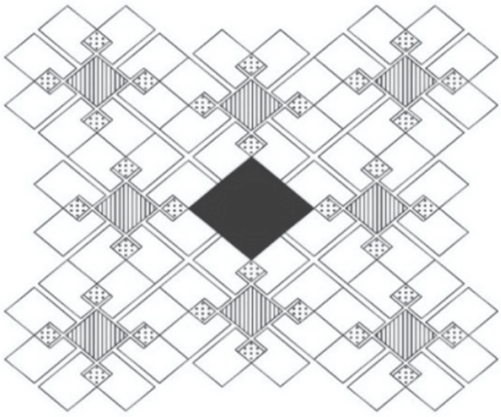

Fig. 2: A sample of the physical pattern of an Islamic neighborhood consisting of 8 neighborhood units and a neighborhood center with mosque orientation

mosque must be posited in a higher hierarchy rather than other uses then the other elements and details of the neighborhood must be organized around the mosque. On the other hand, it has been narrated in this document that "privacy of mosque equals 40 Zeraa, 40 mosques located in four directions of it" (Koleini, 1988). There are other hadiths similar to this narration that have specified the number 40 for determining neighborhood limits. Since the mosque is at the center of the neighborhood and neighborhood boundaries of the mosque are outlined, the approximate area of a neighborhood can be measured by integrating several neighborhood units so that the mosque's neighbors (that sum of them in addition to the mosque and its surrounding context form one neighborhood unit) are forty houses in four directions of the mosque. The reason is that this narration emphasizes the four directions not per direction. It means that when we move from mosque centrality to four directions each direction (north, south, east, west) must cover 40 houses that lead to 160 blocks indicating the boundaries of a neighborhood unit (Raeesi and Mohammad Ali Nezhad, 2021). Now, the boundaries and physical pattern of a neighborhood can be obtained by combining several neighborhood units (Fig. 2). The concept of "familiarity" is determined based on the same neighborhood boundaries that are adopted from the Surah Al-Hujurat (The Rooms): "O humanity! Indeed, we created you from a male and a female and made you into peoples and tribes so that you may ˹get to˺ know one another." (Al-Hujurat/13).

According to verse 13 of Surah Al-Hujurat, God has created people of various ethnicities and branches to allow them to know each other or get familiar with others. The term "*Letaarafou*" in this verse is rooted in the word "*taaroF*" which means knowing each other and getting familiar with others (Keshvari, 2016). Allameh Tabatabaie interprets this verse, "We created you from one father and one mother; all of you are born from two bodies, either you are white or black, Arab or other ethnics; we created you in different branches and races, not for this reason that a race of you is superior with more dignity that others but for just allowing you to know each other and do your social activities, communications, and transactions in a better way" (Tabatabaie, 2018 Subsequently, in case the design of a neighborhood is outlined in a way to make more recognition with inhabitants permitting them to know each other, this information leads to the next quality of social communication among individuals. Fortified nature with other inhabitants gives different points of interest, such as more recognition with others, security, and controlling wrongdoings by moving forward care and forming self-control by tenants living within the neighborhood. Another benefit is improved human relationships as a substantial case in Islamic urban planning, which familiarity is its infrastructure that its development

would facilitate the society management based on the Islamic teachings (Keshvari, 2016). This important point indicates that the quantity and quality of the neighborhood (in terms of area, population, construction pattern, etc.) must result in deepened neighborhood relationships to improve familiarity with neighbors allowing them to know each other, which this case shapes nature of the concept of "familiarity". The most significant requirement for improvement of the concept of familiarity is the relative stability of a neighborhood occupants' residence in a place where they live because the unstable residence of occupants, relocating from one to another neighborhood or city would prevent deepening the neighborhood relationships due to time shortage. The consequence of this case is seen in weak neighborhood relationships and their familiarity with each other threatening the concept of familiarity. This phenomenon has occurred in many contemporary cities of Iran over recent decades (particularly since middle Pahlavi II). In other words, permanent population displacement (between different cities and mainly from villages to metropolises) in recent decades has prevented deepening the concept of familiarity due to the short-term residence of individuals in a neighborhood or city. The mentioned case has led to many problems, such as increased crime rate, social harm, and many other issues affected by the weakened concept of familiarity. This is the situation that which its opposite condition over past centuries in Iran has led to social solidarity in neighborhoods of traditional cities, and subsequently the participation of occupants in neighborhood affairs (Shieh, 2005; Pakzad, 2003; Habibi, 2001). This process has changed the type of social solidarity and participation of occupants in the affairs of the neighborhood, reduced the social harm and crime rate, and led to many other advantages in traditional Iranian cities. The following section explains why macro-popular displacements have occurred and why the concept of familiarity has been weakened in contemporary Iranian cities.

Reasons for weakening the taarof concept in contemporary Iranian city

Villages played an important and effective role in economic, social, and political relations in the early Qajar period, because agriculture was the dominant action, so villages had an effective position in economic relations. Land tax was the main source of income for governments, so villages were at the center of attention of the governing system. In the late Qajar era, the formation of an industrial system in the European method gradually made cities important, which changed the economic production that in turn led to cultural and social changes. Therefore, the power was transferred from villages and nomads to the cities, which obtained political success (Shahesmaili Nezhad Khorasani and Azadarmaki, 2020). No industry or factory was concentrated in cities of Iran to gather the population in the city before that time. In late Qajar, Iran's population increased, which provided the field for dividing the complicated work. In terms of job and employment system complexity in the current world, Giddens believes that there are three important market capacities: property owner, educational and professional competencies, and manual labor force indicating that there are three major categories in the contemporary community: upper-class (those who own most of the properties), middle class (those who exchange their proficiencies and skills in the market), and lower class or low-income class (who sell their manual works). The triple residential patterns are created based on the three available social classes (Mahdavi Vafa *et al*., 2009). The severe urbanism process and transition to industrial life occurred after the Pahlavi era in Iran; hence, modernist ideas especially in the industry sector led to considerable migration from villages to cities during this period (Foran, 1992). The most important reasons for this migration flow are land reforms, increased oil revenues, and incomplete implementation of civil and economic development plans without considering the principles of land-use planning (Abadian, 2018). The consequence of these factors led to fundamental changes in the ratio of urban to rural population, so the urban population of Iran increased from 31% to 74% during 60 years (1956-2016), while the inverted situation occurred for the rural population and rural population that made up more than 65% of Iran's population in 1956 has declined to 25% (Fig. 3). The effect of each factor affecting the creation of migration flow from cities, and the subsequent formation of the concept of displacement and weakened concept of familiarity are explained in the following sections.

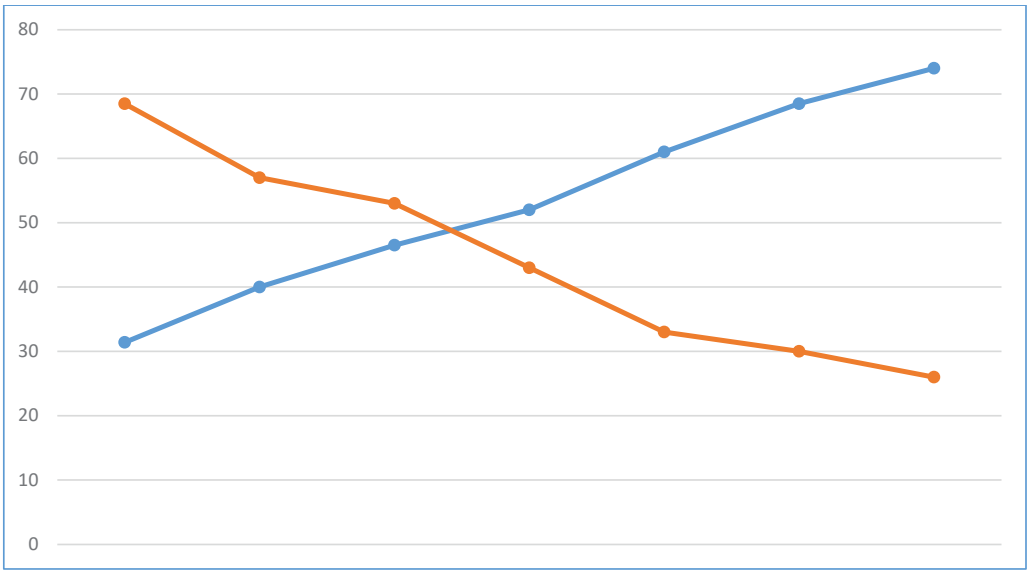

Fig. 3: Variation in the urban population (blue line)-to to-rural population (red line) ratio in Iran from 1956 to 2016

Effect of land reforms

Land reforms were the most significant reason causing migration from villages to cities, which was a determinant measure in weakening the agriculture of the villagers. These governmental measures were highly determinant and effective, so village life can be divided into two parts before and after land reforms (Saiedi, 2001). The rate of migration from far and near villages to mega cities, especially Tehran was intensified from 1963 to 1978. After land reforms, various factors increased villagers' migration the most important ones included the lack of yield of the divided lands caused by extensive land division, the noneconomic nature of activity in the lands that required the formation of agriculture cooperatives, the prevalence of hoarding, brokerage and speculation, usury, and small and large debts of farmers to the agriculture bank making farmers to sell their lands and go to Tehran to find job. In this period, various workshops and industrial or semi-industrial factories were created in Tehran and marginal areas, and these centers needed rural professional and semi-professional laborers. The labor forces from all around Iran went to Tehran to find jobs in industrial centers, while they had no occupational guarantee for their future. Employers usually recruited them for daily wages, so they would be fired without minimum social insurance when the employees did not need them (Abadian, 2018). Therefore, they had to find new jobs and new places for settlement subsequently. This plan led to dramatic changes in the number of employees in the country so that farmers who had the highest number of employees in Iran before land reforms lost this majority after the implementation of this plan because they became unemployed in villages and migrated to cities. Now, farmers make up only 15% of the employees in Iran. After land reforms, owners' lands were distributed among villagers, but they had no money to cultivate these lands; therefore, agricultural lands had no fertility. When land reforms started, no cooperative system existed in the country to allow owners of small lands to farm together and divide the obtained profit. More importantly, small lands had no economic value for cultivating products in them. Hence, most peasants sold their lands and migrated to metropolises, such as Tehran to find jobs (Abadian, 2018). According to research achievements in 1965, around 62% of migrant workers in Tehran were simple workers, 12% of them included semi-skilled workers, and 14% of them were skilled workers. According to documented reports done by the Social Research and Study Organization in 1972, 91% of custodians

in Tehran working in public places, noble houses, and government offices were from rural migrants. The remaining 9% of custodians migrated from small cities to Tehran. In General, 72% of this statistical group included farmers and small owners (Abadian, 2018). This group was mostly farmers who had lost their jobs and had to migrate due to land reforms.

Effect of increased oil revenues

In the urban system of the oil-depending countries, an underlying development appeared making a deep connection between these countries and capitalism after oil discovery and obtaining oil revenues since the early 20th century. Oil discovery in these countries led to capital concentration and increasing growth of cities, subsequent development of infrastructures and constructions, and formation of comprehensive concepts that entered these cities into a new phase (Witlox and Derudder, 2007). In other words, oil discovery is a critical point in urban-planning developments linking urban planning to mechanisms of capitalism and liberal schools in those metropolises depending on the oil economy, including Iran's metropolises (Wiedmann *et al*., 2012). In terms of political economy, the consequences of this phenomenon in less-developed countries include the entrance of many workers who do not know the industrial culture and a mass of middle classes without any horizontal and vertical bond (culturally and socially) to urban areas. Therefore, both groups take advantage of the city centers and their worn-out fabric. While the just-arrived classes and young households formed among the upper middle class have considered high-quality spaces, the central fabric tests the social groups in the same way (Raies Dana, 2002). In Iran, the construction rate and civil engineering activities also capital accumulation in the form of fixed capital are considerably affected by the oil revenues since the significant role of profit in capitalist relations in oil countries, speculation, and rent play an important role in civil engineering activities. Finally, the consequence of these relations and interactions appears in the form of a spatial gap and the farthest distance between the city and the village (Imani Shamlou *et al*., 2016). Hence, such a gap leads to migration from deprived areas that are villages to more prosperous areas that are cities, especially metropolises. It is worth noting that, unlike land reforms that had an effect range in macro scale and territory zone (displacing from villages to cities), the entrance of high oil revenues to metropolises led to population displacement at moderate and intracity scales in addition to macro and territorial scale due to lack of balanced distribution in geography of metropolises. The result of such population displacement led to the advent of some concepts, such as uptown and downtown in contemporary metropolises. According to statistics, Iran's metropolises have been always dominated by capital accumulation and turnover relations resulting from oil revenues. Hence, oil revenues led to modernization and new constructions after 1973 (Imani Shamlou *et al*., 2016). Because this capital accumulation and turnover was concentrated in certain areas of the metropolises, this process broadened the class difference and subsequently intensified the migration to more privileged areas. In the book "Iran Between Two Revolutions," Abrahamian expresses, "Social-economic development was achieved due to increasing oil revenues. Oil revenue that equaled 555 million dollars in 1963 reached 958 million dollars in 1968, 2.1 million dollars in 1971, 50 million dollars in 1974, and 20 billion dollars in 1976 after the price of oil was quadrupled in world markets. Total oil revenues reached 13 billion dollars in 1964-1974 and reached 38 billion dollars between 1974 and 1977" (Abrahamian, 2007). However, the Pahlavi government could not effectively use these increased incomes to reduce the difference between cities and villages; on the contrary, higher oil revenues widened the gap between cities and villages due to the wrong policies. The development obtained from oil revenues led to the widened gap between urban and rural revenues, agriculture recession in villages and indiscriminate migration to cities, hidden unemployment in cities, income inequality in urban areas, and a wider gap between social classes due to these wrong policies. Hence, only 2% of the urbanist population assigned 40% of the costs to themselves until the mid-1970s (Amid Zanjani, 2002). In this period, reliance on higher oil revenues enhanced the service sector and public systems without planning, so this sector became big falsely. A considerable breakdown also occurred in terms of financial distribution; the banking system made rich people richer and the poor poorer, and

the low-income class tolerated the highest load of inflation, lack of a plan, financial corruption, and an unsound economy. Therefore, migration to cities multiplied the population of some cities over one decade (Amid Zanjani, 2002). Although villages received considerable attention after the Islamic Revolution based on the bases and mottos of the revolution, migration from villages to metropolises continued because a major part of oil revenues was spent on the service sector, and the geographical scope of these services was mainly concentrated in metropolises.

Effect of economic development without considering principles of land-use planning

If economic development is done in an unbalanced way without considering land-use planning principles, this case would lead to large population displacements from deprived areas to privileged areas. The economic plan of Pahlavi II was unbalanced, while urban and central areas had rapid growth experiencing more consumption, marginal and rural areas were at risk of facility shortages and bad health situations, which led to considerable migration flows. In general, urbanism growth in Iran was slow from 1921 to 1961 in Iran, urban population growth equaled 2.65% and natural population growth was 2.12%, and 0.53% of cities' population comprised rural migrants. During the 15 years from 1961 to 1976, however, urban population growth equaled 4.42% while the natural growth of population was 2.77%, and the rate of rural migration equaled 1.65% in this period. Accordingly, the urban population of Iran equaled 31.4% in 1956, exceeded 40% in 1966, and the urban population of Iran reached 48% in the revolution of 1978 while the previous migration process continued after the revolution, and the population balance between the city and village disappeared. Urban and rural population balance became equal in 1981, while the urban population made up 71.5% of the total population in 2012, and now 75% of the whole population lives in cities based on the reports published by the Statistics Center of Iran (Abadian, 2018). According to available reports, the population-to-hospital bed ratio equaled 940 people in 1967, but the hospital beds were fully distributed in an unbalanced method; for instance, 2556 beds existed in the central province (with Tehran centrality), and 1089 beds were available in Tehran, while there were 15 beds in Headquarters of Ilam, 175 beds in Lorestan Province, and 105 bed in Baluchistan. Therefore, there is a high concentration of physicians, hospitals, and beds in the central province with the centrality of Tehran; also, the bed ratio was more critical in villages. According to official statistics, around 47% of physicians and 57% of dentists lived in Tehran in 1973. Although there was one physician per 880 people in Tehran, one physician was available per 14900 and 12500 people in Ilam Headquarters and Zanjan Province, respectively (Asghandi, 2005). Public education and health status were not developed in line with the needs and population of each area so educated people and educational facilities in megacities were more and better than the marginal cities and villages. In this lieu, the improper status of the rural economy and the increasing attraction of megacities and central cities resulting from economic and service activities accelerated the migration of rural laborers to cities. According to consensus in 1976, around 97% of rural migrants entered the metropolises, such as Tehran, which had the first rank by accepting 50% of the migrants due to more requirement rate in service-based jobs. The extraordinary population rise in Tehran indicates that this city has followed the concept of priority and single-city domination in the urban system and neglected the principles of land-use planning. This kind of development is matched with capitalism's pattern through which, relocation is confined only to certain areas of the country so that some areas are evacuated in favor of a certain area. Moreover, due to non-independent development, third-world countries show a different face and features so that most of these countries experience a higher rural migration rate, and this is the same case that occurred in contemporary Iran over recent decades (particularly since the mid-years of Pahlavi II then).

Effect of municipalities' income generation system

In addition to the three mentioned factors their effects are seen at the territorial scale and large population displacements from villages to cities, a fourth factor also affects the population displacements and subsequently the weakened concept of familiarity. Unlike the three previous factors, the effect range of this factor is at middle scale and intracity displacements. The fourth factor is

Table 3: Factors affecting the weakening concept of familiarity in contemporary Iranian cities in terms of political economy

Factor	Type of nexus between the factor and other factors	The main context of the factor	The scale of effect on the concept of familiarity
Land reforms	Transverse	Political economy	Macro (territorial scale)
Injecting high oil revenues to metropolises	Transverse	Political economy	Mostly macro and sometimes at middle scale (in both territorial and intracity displacements scales)
Economic development without considering principles of land-use planning	Transverse	Political economy	Macro (territorial scale)
Municipalities' income generation system	Transverse	Political economy	Mostly for middle deciles and at the scale of intracity displacements but sometimes for poorer deciles, macro and intercity displacements scale in the territorial zone.

the municipalities' income generation system in Iran, whose major part depends on the incomes gained from issued construction licenses and selling density in particular. Therefore, the contribution of unstable income (especially selling density) out of total urban management revenues now exceeds 50% or even 70% in most of the metropolises of Iran. Because the urban planning system of Iran is based on severe control over city areas, the land supply in legal areas of metropolises has been considerably limited over recent decades. Under such circumstances, any type of density-selling and license issuance for increasing height or building density is considered economic rent and is given to capitalists and property owners who can afford to buy the surplus density not to the poor classes and tenants who do not own a house. However, what happens due to this density rise is the price of the land and property density rise has been approved for them- will be more stimulated. The reason is that under severe constraints imposed on land supply and prevention of horizontal expansion of the legal area of the city, the price of lands and properties that received surplus density and vertical expansion license will be increased. Such a price rise would not have occurred if the surplus density was not approved. In other words, giving surplus construction density and higher housing supply through selling density would lead to land inflation and higher prices due to the value-added created in this market. Subsequently, unlike what is assumed, these measures not only cannot control the housing price but also leave a reverse effect on the housing price, causing a housing price rise and a decline in the rate of access to housing. For instance, various statistics over recent years have shown that the highest housing price rise has occurred in some districts of Tehran, which not only are not facing a housing shortage but also have a greater number of vacant houses in these districts (northern district of Tehran). This case indicates the significant relationship between selling density and house price rise. Therefore, selling density, which is the main strategy for municipalities' income generation in metropolises of Iran could solve the issue but caused land inflation and higher prices due to the value-added created by it leaving to reverse effect on the housing price unlike what is assumed in the early stage. Therefore, the strategy of selling density has intensified the reduction in housing access rate and subsequently weakened the concept of familiarity because the effect of density-selling on the asymmetric and unbalanced rise of housing prices in metropolises has widened the class difference and spatial Gini Coefficient in metropolises. This case has made the poor class poorer and the rich class richer. This widened class difference has intensified the displacement phenomenon, especially in the middle class of the community; hence, a considerable part of the community (poorer deciles and middle deciles of the society) has faced more pressure on access to affordable housing due to such strategy because they cannot find a house based on their needs in their demanded districts and neighborhoods. Therefore, the phenomenon of relocation and population displacements between different urban districts would be intensified. In other words, this kind of income generation system

for municipalities would direct the middle deciles and classes of society towards poorer deciles by intensifying the class differences and widening the spatial Gini coefficient. The consequence of this issue is the lack of deepened neighborhood relationships weakening these relationships due to constant population displacements leading to a weaker concept of familiarity in contemporary metropolises of Iran. Table 3 has reviewed the factors affecting the weakened concept of familiarity in contemporary Iranian cities in terms of political economy.

According to Table 3, the nexus between the four factors is transverse, not longitudinal; it means that the reasons are not considered before each other in terms of the origin of the causes, so all of them affect the weakening concept of familiarity in contemporary Iranian city within a transverse hierarchy parallel to each other. In terms of the effect scale, it can be stated that unlike land reforms and lack of balanced land-use planning that have had a macro effect on the territorial scale, high oil revenues affect both territorial and urban scales. So, the unbalanced distribution of oil incomes and rents resulting from them in the geography of cities, especially metropolises, has sometimes led to population displacements and relocations inside the metropolises (between deprived and privileged areas). This case is seen at the severer level in the factor of municipality's income generation system, and the effect of this factor is seen on the middle deciles of the community, mainly at the average level and intracity displacements scale, while sometimes is seen for poorer deciles, macro level, and scale of intercity displacements. Based on the comparison of the research background with the discussion presented in this study, what can be stated as the main finding of this research is that since the middle years of the Pahlavi Government, the political economy's evolutions led to the advent of displacement phenomenon at the national level and large flows of migration to metropolises in the frame of some factors, such as land reforms, government dependence on the high oil incomes, and economic development without considering the requirements of land-use planning. The mentioned issue weakened the neighboring relationships because the ratio of rural to urban population ratio was changed due to relocation, extensive migration flows, and numerous demographic displacements that occurred in the territorial zone over several decades. Therefore, these migrations and numerous displacements made many Iranian households enter metropolises (mostly marginal and poor areas of metropolises) as a new space to live there. On the other hand, most of these households who were rural farmers did not have permanent and fixed jobs in the new city (mainly metropolises), so had to look for different jobs during seasons to live their lives. Therefore, a major part of migrants had to experience the relocation phenomenon again under the new conditions after migration because they had no constant job. Hence, these frequent displacements of residence places at the scale of migration from villages to metropolises and also at the scale of intracity displacements from one area to another, and lack of a constant job made frequent breakdowns in the neighboring relationships preventing them from being deepened. In comparison with other urban fabrics, therefore, many social harms such as insecurity and higher crime per capita rates occurred in the areas where migrants lived because the concept of familiarity was weak in these districts. In addition to three factors of land reforms, the dependence of the government on the high oil incomes, and economic development without considering requirements of land-use planning over recent decades, a fourth factor titled municipalities' income generation system was added to the effective factors weakening the concept of familiarity in contemporary Iranian cities. This factor mainly affected the middle scale of intracity displacements. Therefore, the most important requirement for deepening the neighboring relationships and stabilizing the concept of familiarity in contemporary Iranian cities is revising macro political economy policies to stabilize the citizens' residence in a place by adopting accurate policies. This stabilization would make longer neighboring relationships and deeper familiarity between neighbors allowing them to know each other better. This is a promising case for a relative solution for displacement and lower social harms caused by the weakened concept of familiarity in the contemporary Iranian city (Fig. 4).

The emphasized and innovative aspect of this study compared to other studies is the research background cited in this study. Although these studies have examined a certain aspect of displacement and relocation in contemporary Iranian cities, none of them has firstly provided a comprehensive and multifaceted view of the field of political

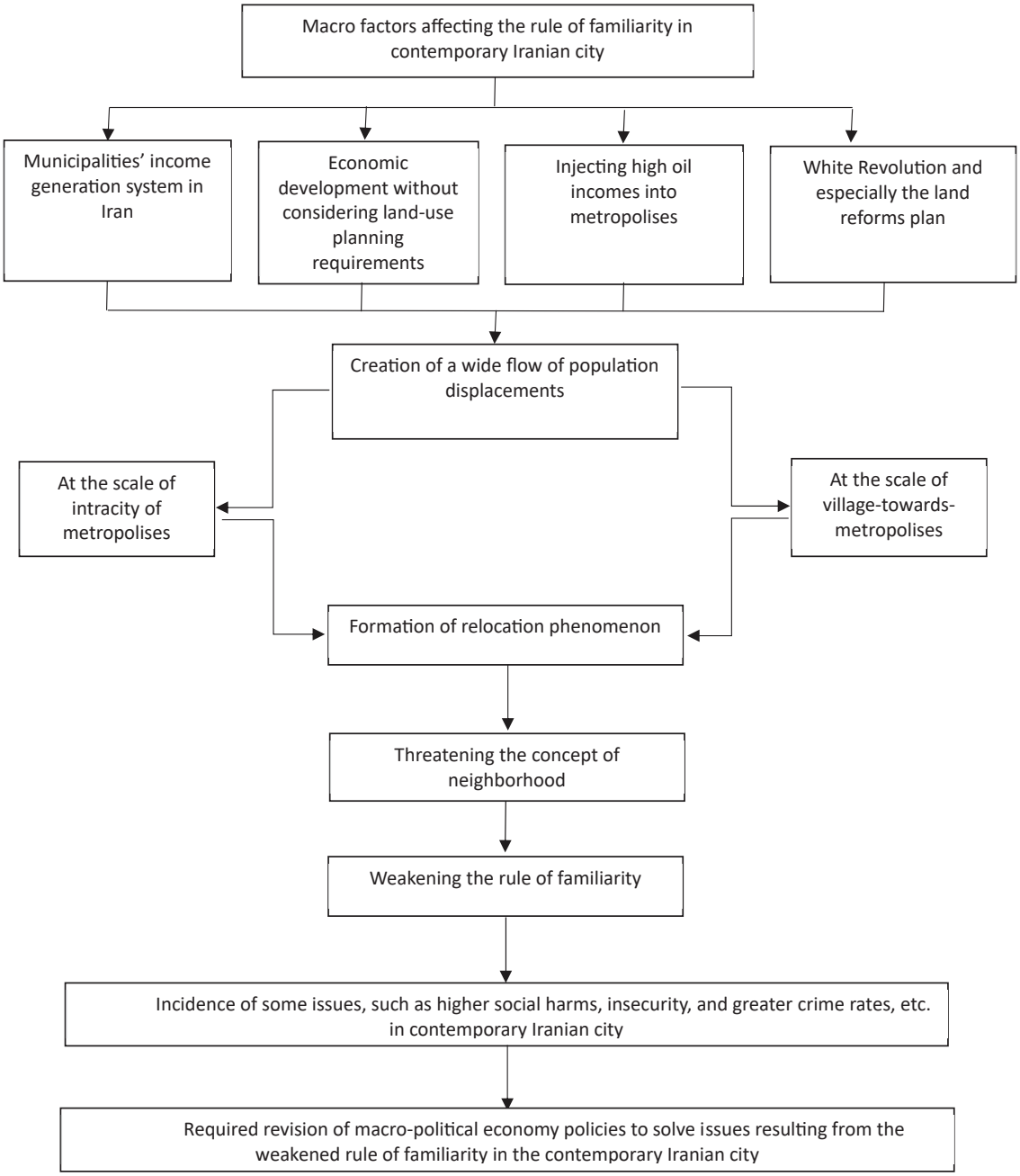

Fig. 4: How factors affect the weakening concept of familiarity in contemporary Iranian cities and conditions required for solving the resulting issues

economy. Secondly, none of them has considered the relationship between this issue and the concept of familiarity (which is one of the most important concepts in an Islamic city). These two shortcomings were covered in the extant study forming the innovative aspect of the current study

CONCLUSION

Based on the discussion and findings, it was determined that the concept of familiarity that is adopted from Quranic teachings has a considerable influence on the neighboring or neighborhood concept. However, the evolutions in the contemporary Iranian community have left this concept in serious challenges over recent decades, causing underlying developments in the concept of neighborhood. In this study, it was tried to find how changes and developments in the political economy have threatened and weakened the concept of familiarity in contemporary Iranian cities and what strategies should be adopted to prevent these threats. The essential factor for confirmation of the concept of familiarity is a Quranic concept, and the requirement for the realization of the desired Islamic city is deepening the neighborhood relationships. The reason is that the deeper these neighborhood relationships and interactions, the more familiarity among neighbors will be. Subsequently, neighbors more know each other in a neighborhood, leading to more social solidarity, less social harm, a higher security rate, and fewer crimes in the neighborhood among other benefits related to familiarity among neighbors allowing them to know each other better and deeper. It is worth noting that this study would complete the findings about why the concept of familiarity has been weakened in contemporary Iranian cities by relying on the library documentary references and logical reasoning of the results reported in this research and using other research methods (including qualitative methods, questionnaire, etc.). Further studies can be done to complete and accomplish these results. To complete this study, researchers can focus on such issues as examining the quality and conditions of achieving the concept of familiarity (taarof) in extra-local scales (such as urban, national, and international scales), examining other Quranic and Islamic concepts that are effective in strengthening the concept of taarof, evaluation of the quality and quantity of the concept of taarof in traditional cities, especially in the early days of Islam by citing historical sources, explaining the jurisprudence and legal rules necessary to strengthen the concept of taarof in the Iranian Islamic city.

AUTHOR CONTRIBUTIONS

M.M. Raeesi has performed the writing of the original draft, investigation, methodology, and supervision.

ACKNOWLEDGEMENT

The author would like to thank the encouraging words and comments from all the editors and reviewers who have provided valuable contributions to this manuscript.

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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HOW TO CITE THIS ARTICLE

Raeesi, M.M., (2024). The quiddity of familiarity concept (taarof concept) and reasons weakening it in contemporary Iranian cities. Int. J. Hum. Capital Urban Manage., 9(3): 457-472.

DOI: 10.22034/IJHCUM.2024.03.07

URL: https://www.ijhcum.net/article_711855.html

Int. J. Hum. Capital Urban Manage., 9(3): 473-488, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Digital marketing: consumers' purchase intention towards e-commerce platform for urban region

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ARTICLE INFO

Article History:
Received 12 October 2023
Revised 26 January 2024
Accepted 02 February 2024

Keywords:
Brand awareness
Digital marketing
E-promotions
Perceived convenience
Personalization

ABSTRACT

BACKGROUND AND OBJECTIVES: One of the "15 Guiding Principles" designed to achieve the 2030 aim highlights the importance of giving priority to exploration in the digital economy as a crucial element in defining the future economy. Consumers' interest in using social media and e-commerce platforms for their shopping activities is rising in this day of modern technology. However, based on a study conducted by the Small Medium Enterprise Corporation indicated that a substantial majority of small and medium enterprise entrepreneurs acknowledge the importance of incorporating digital technology into their fundamental business operations. Nevertheless, there is a noticeable discrepancy between the level of awareness regarding these technologies and their actual adoption. Therefore, the research objectives are to determine the relationship between perceived convenience, E-promotion, brand awareness, and personalization toward consumers' purchase intention.

METHODS: Data was collected from a wide range of individuals in urban areas using probability sampling methods. This study aims to gain a deeper understanding of the various factors that can impact individuals' intentions. A sample size of 385 participants from the e-commerce sector in the Klang Valley, Malaysia. Therefore, stratified sampling is employed by considering pertinent characteristics such as location, age, and intention to use e-commerce. The analyses were conducted using SmartPLS software to measure the influence of digital marketing on consumers' purchase intention.

FINDINGS: The variables of E-Promotion (β=6.601, $p<0.05$), Brand awareness (β=3.975, $p<0.05$), and Personalization (β=4.152, $p<0.05$) had a statistically significant impact on Customer Purchase Intention. Nevertheless, the variable of Perceived Convenience does not have a significant impact on Purchase Intention (β=1.646, $p<0.05$). Consequently, e-promotion was deemed the most influential component, followed by personalization in second place, and brand awareness in third place.

CONCLUSION: The findings are expected to assist businesses in identifying the factors that influence the purchase intentions of urban consumers on an e-commerce platform. These encompass micro, small, and medium-sized enterprises (MSMEs), which serve as the foundation of Malaysia's economic development. The process of digitalization is anticipated to enhance opportunities for micro, small, and medium enterprises (MSMEs) to grow and flourish. The potential of digitalization to enhance integration across economic sectors and promote cost effectiveness through a collaborative economy is evident. This aligns with the goals stated in the My Digital Economic Blueprint, which is scheduled to be implemented by 2030.

DOI: 10.22034/IJHCUM.2024.03.08

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
48	2	7

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

There are "15 Guiding Principles" that have been set to achieve the target by 2030, one of the guiding principles is the future economy where exploration in areas of the digital economy is given priority. The impact of the digital economy is wide-ranging and transformative. It can influence society, business, and government. The opportunities digital economy for businesses such as online businesses provide channels to expand market reach domestically and globally; and greater opportunities for local products to be marketed and sold via e-commerce (MyDIGITAL, 2021). Since the formation of the modern state of Malaysia in 1963, Wahab *et al*. (2022) assert that Klang Valley has been at the forefront of development. Klang Valley, like other cities in developing countries, has undergone substantial urbanization and is regarded as the fastest-growing region (Department of Statistics Malaysia, 2011). The urbanization rate in the Klang Valley has surpassed 91.4%, and the region's economic growth can be enhanced by e-commerce, which will generate new job opportunities. E-commerce platforms often provide small business owners with the opportunity to broaden their market penetration. This phenomenon possesses the capacity to foster innovation and contribute to the growth of the urban economy. Moreover, the enhanced availability of goods facilitated by e-commerce has the potential to boost urban economic activity and consumption. Therefore, the engagement of the urban population with e-commerce platforms is likely to impact the various aspects of urbanization (Somasundram, 2020). From a business perspective, digital marketing strategies are more effective than traditional ones at raising brand awareness and garnering consumer feedback (Sama, 2019). Digital marketing includes websites, mobile apps, social media, and digital collaborations. These platforms allow companies to advertise and promote their goods, and consumers may browse posts, and share their experiences associated with the products and services (Sama, 2019). Wherein, E-commerce is a platform for buying and selling products or services through the internet. A digital marketing and e-commerce platform are interdependent, with the help of digital marketing, e-commerce may generate a significant amount of revenue by assisting in the acquisition of customers and the creation of brand value. In this age of advanced technology, consumers are increasingly interested in utilizing e-commerce and social media applications for their shopping activities. Websites, mobile apps, social media, and online partnerships are all examples of digital marketing which has a major impact on consumers' shopping behavior. E-commerce uses digital marketing techniques to increase brand value and attract new clients to generate significant revenue growth. Consumers no longer only rely on traditional material or word-of-mouth recommendations when evaluating a purchase in today's market. As highlighted by Tran *et al.* (2020), they aggressively seek out and prioritize product reviews across numerous channels where the product is available. Customers view articles and share them, and companies can advertise and promote their products on these platforms. Additionally, Opeodu and Gbadebo (2017) have emphasized the important role that advertising plays in influencing consumer choices across a range of digital media channels. The significance of digital media platforms in influencing customer choices and purchasing behavior is highlighted by this. E-commerce uses digital marketing to generate revenue because it helps build brand value and a consumer base. Before making a purchase, customers study the product reviews on all the platforms where the product is listed rather than relying primarily on the content or word of mouth (Tran *et al*., 2020). According to Opeodu and Gbadebo (2017), who examined the impact of several digital media platforms, advertisements on these platforms are crucial in influencing consumers' decisions.

Problem statement

The profound impact of technological advancements on business operations and growth is undeniable. There is a growing trend among businesses to utilize technology as a means of optimizing their operational processes. Based on the findings of the Shared Property Vision 2030, a study conducted by the SME Corporation indicated that a substantial majority of SME entrepreneurs, 79.7%, acknowledge the importance of incorporating digital technology into their fundamental business operations. Nevertheless, there is a noticeable discrepancy between the level of awareness regarding these technologies and their actual adoption. As reported by Izwan (2022) in the New Straits Times, Azlan Ahmad, The Access Group's (AG) head of Startup and Small Business

Sales, stated that many SMEs are largely focused on ensuring their immediate sustenance that they do not have the time to consider the long-term benefits of digitalization or the potential consequences of not embracing it. There are "15 Guiding Principles" that have been set to achieve the target by 2030 by the government, one of the guiding principles is the future economy where exploration in areas of the digital economy and cashless be one of the attributes given priority (Minister of Economic Affairs, 2019). Naeem (2019) stated that many firms are researching how technologies of social networking influence consumers to exchange what they need and want. Therefore, it shows that there is a gap between SME entrepreneurs from different industries in using the digital economy as they are at different levels of digital literacy in business. Several intriguing scientific areas deserve further study. According to Saima and Khan (2020), future research should explore the influence of influencer marketing in social media from various angles, such as brand awareness. According to Chen *et al.* (2018) additional factors should be incorporated into the study of social commerce to achieve different outcomes regarding the purchasing behavior and intention of consumers. Additionally, according to Dakduk *et al.* (2020), more surveys and comparisons on the use of mobile services need to be conducted in various technological contexts to better understand the relationship between the digital environment and purchasing behavior. Researcher Sama (2019) made a similar suggestion, stating that future studies should focus on a new digital medium that influences consumers. Future studies are anticipated to include an array of attributes, including information accessibility, usability, and interaction (Liu Yang *et al*., 2019). Therefore, the research objectives are to determine the relationship between perceived convenience, E-promotion, brand awareness, and personalization toward consumers' purchase intention.

Literature review

Underpinning theory

The Stimulus-Organism-Response (S-O-R) model explains how the environment (Stimulus) might affect human behavior (Mehrabian and Russell, 1974). Different environmental cues operate as stimuli and influence the internal experience of people (Organisms), which in turn causes people to react (Armawan *et al*., 2022). According to Liu *et al*. (2019), an individual's thoughts and feelings are their organism, meanwhile the individual (Response) because of the stimuli (Koay *et al*., 2021). The S-O-R model is commonly applied to identify a consumer's behavior in an online platform. Hence, the S-O-R model is used in this study to identify the purchase intention of a consumer with the influence of digital marketing in an e-commerce platform. Therefore, the stimulus of this research is digital marketing consists of perceived convenience, e-promotion, brand awareness, and personalization. Digital marketing influences the consumer as organisms to react toward consumers' purchase intention either to buy or not.

Purchase intention

Purchase intention refers to the willingness of a consumer to purchase any products or services. It can be seen as a primary market forecast response for determining the impact of consumer purchasing behavior, incorporating the demand for new products (Mathew and Soliman, 2020). Purchase intention is generally used to examine the new distribution channel's implementation to guide managers to determine if the concept is worth further development and decide on their geographic markets and consumer segments to target through the channel. Their significance lies in the fact that intentions are reflected as the key predictor of actual behavior. Then, the study is of the utmost importance for the success of any e-commerce platform (Pena-Garcia *et al*., 2020).

Digital marketing

Digital marketing is defined as a proposal of traditional marketing where the strategies and drives are on the internet. Digital marketing has become a sensation that carries out customization and distribution together to achieve marketing goals. Digital marketing is a combination of technology intersection and multiple devices such as smartphones (Mathew and Soliman, 2020) which creates a new phase of concept to do marketing on the Internet. The technologies have contributed to digital marketing advancement, for instance, advertising through display, affiliate marketing, marketing of search engines, email marketing, mobile marketing, and social media marketing (Dwivedi *et al*., 2019). Digital marketing content which is known

as "activities" refers to the matters of accessibility of available electronics and a value creation process such as creating, communicating, and delivering value to customers and stakeholders (Mathew and Soliman, 2020). According to Dwivedi *et al*. (2019), companies should make sure to pay attention to align their organization's objectives with digital marketing, and also marketer needs to understand how digital advertising affects customers (Stewart *et al*., 2018). Digital marketing space is important as where it enables companies to reach their customer as they make strategies for effective development, delivering the right information, and enriched innovations (Mathew and Soliman, 2020). This is because a huge amount of people will access online to search and obtain information about a product (Stewart *et al*., 2018) to decide on digital marketing increases.

Perceived convenience

Convenience refers to whether a process, goods, or service is expected to enhance the easiness of accessibility which saves resources and decreases dissatisfaction. Convenience in e-commerce is recognized as an effort and time saver, for its flexibility of ordering a product at any time and place (Mou *et al*., 2019). Perceived convenience is described as the level of degree for time, place, and easiness of performance that a person feels when using Information Technology (IT) (Mathew and Soliman, 2020). The benefits of convenience and ease of use have a positive influence on mobile digital content (Mathew and Soliman, 2020) and overall expectation of the value of e-commerce (Mou *et al*., 2019). For example, the convenience of using digital content marketing will increase the desire to use it in selecting products and services based on the tourism industry (Mathew and Soliman, 2020). According to Mou *et al*. (2019), buyers' objectives are to spend less money and involve less risk in buying a product anytime and anywhere manner. Furthermore, they have also mentioned that mobile devices' compatibility is essential as it will increase the convenience perception. Therefore, consumers are motivated to choose e-commerce because of the features where it can compare prices and collect information quickly which seems effortless. According to Mathew and Soliman (2020), perceived usefulness is the stage at which an individual perception about the results, and also, they also believe it is effortless if there is a new technology. They have stated that perceived usefulness impacted the consumer's attitudes to technology use. It has a positive influence and is playing a strong role in shaping consumer behaviors toward shopping online as well as influencing the pattern of digital marketing. In addition, it has been asserted that the perceived usefulness of mobile technology and mobile digital content significantly impacts the convenience associated with their utilization. Furthermore, the level of user-friendliness is associated with the consumer's perception and desire for a seamless experience when utilizing the network. Pena-Garcia *et al.* (2020) have asserted that there exists a favorable influence on the consumer's perception of electronic commerce. The simplicity of the online shopping process contributes to a favorable perception of e-commerce among online consumers.

H1: Perceived convenience has a relationship with consumers' purchase intention.

E-promotions

Promotion plays a crucial role in the marketing mix strategy. The primary objective of promotion is to attract and retain customers, thereby stimulating their interest in purchasing or repurchasing a company's products and services. Additionally, it aims to persuade customers to switch their brand preferences from one to another (Zhu *et al*., 2020). Coupons, rebates, discounts, promo codes, and buy-one-get-one-free offers are all examples of promotions that businesses use to entice customers to purchase their goods. When these promotions are conducted online, they are referred to as "E-Promotions" (Zhu *et al*., 2020). E-promotion, also referred to as electronic promotion, is a contemporary approach that leverages technology to conduct promotional activities through online platforms. It is a marketing campaign that is used to communicate by an organization about the benefits of the product to the potential target market to inspire and stimulate quick responses to the sales of goods and services and increase the sales volume (Hanaysha, 2018). Additionally, the e-commerce platform often announces discounts and which products are in sale before the e-promotion is stated to attract customers, as well, consumer welcome the e-promotion based on social compound, the strength, and range of promotion (Khouja and Liu, 2020). Promotions are

carried out by companies to encourage consumer purchases and fast responses as to where the benefit of promotion will influence consumer purchase intention. According to Hanaysha (2018), promotion is a predictor of consumers' behavior and choice of brand and consumers are responding positively when experiencing promotions which significantly affect consumer purchase intention. However, some buyers often complain about the increase in price before the e-promotion which might change their options for a retailer, and after the e-promotion, consumers participate in it which will change the perception of the brand and retailers (Khouja and Liu, 2020). It shows that immediate consumer behavior changes are traced when a promotion is offered among online buyers.

H2: E-promotion has a relationship with consumers' purchase intention.

Brand awareness

Brand awareness is a marketing term that refers to the extent how much a consumer recognizes a product by its name. Building brand awareness is a vital step towards promoting a new product or reviving an older brand. Generally, brand awareness creates a set of qualities that distinguish the product from its competition. According to Koay *et al.* (2021), establishing brand awareness is commonly regarded as a fundamental factor for the survival of businesses. This is achieved through active engagement on social media brand pages, which involves the dissemination of information and communication with both new and existing customers. The primary objective of these efforts is to cultivate brand awareness plus enhance brand image, in the end leading to increased sales of the products offered. Researchers Saima and Khan (2020), asserted that a positive brand experience will lead to a stronger consumer base. Therefore, it can be said that a product that has more brand awareness is known to generate more sales. Depth means the process of making it easy for a consumer to recall a brand of a product, while width indicates a situation where, at the time of purchase, the brand name of a product comes to the consumer's mind immediately (Chi *et al.*, 2009). When the depth and width of the brand of the product work at the same time in the minds of consumers, consumers will choose to purchase the product. This shows that the product has high brand awareness and that it will generate a higher rate of sales. Hence, brand awareness is identified to have a strong influence on product selection and can act as a basis of consideration when purchasing a product (Hasan and Sohail, 2020). Moreover, there is a positive correlation between purchase intention toward consumer willingness to acquire a product. Purchase intentions can serve as a significant indicator for forecasting consumer behavior. A positive commitment is when the customers have the intention to purchase which encourages consumers to make the real purchase. Hence, it is known that a high level of brand awareness can develop a customer's purchase intention. Hasan and Sohail (2020), mentioned that brand awareness variables on consumer's purchase intention showed a positive and significant effect.

H3: Brand awareness has a relationship with consumers' purchase intention.

Personalization

Personalization brings forward the meaning of meeting the needs of the customer more effectively and efficiently, making interactions faster and easier and therefore increasing customer satisfaction and the likelihood of repeat visits. This is achieved when the system tailors an experience based on previous consumer behaviors. For instance, Shoppe customizes its home page for each user based on their search history and the products that they have browsed previously. The main concern of an e-commerce marketing platform is that the content that is marketed should be tailored according to the preference of the consumer. Researcher Liu *et al*. (2019) have mentioned about two types of personalization that occur before and following an online search, highlighting the various consumer aims for each type. One of the main advantages of personalization is a decrease in overloaded information by providing customers with the right information they are looking for. Previous studies also found that a personalized offering will attract the attention of a customer, and increase the purchase intention (Liu Yang *et al*., 2019). According to the researchers Liu Chao *et al*. (2019), found that one aspect of marketing communication that can be significantly managed through the personalization of online shopping platforms is preserving face (reputation) within a group, which is relevant for a prospect who may be influenced by Confucian values.

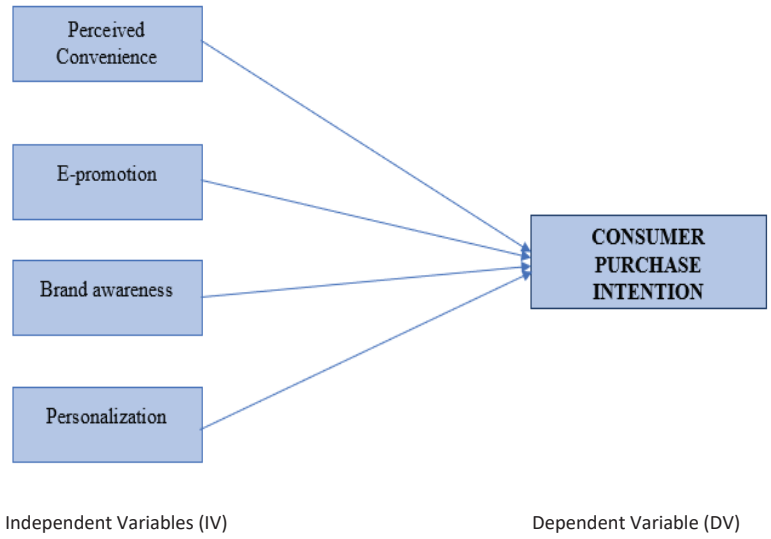

Fig. 1: Conceptual framework

H4: Personalization has a relationship with consumers' purchase intention.

Fig. 1 shows the conceptual framework which lies in the independent and dependent variables. The independent variables for this research are perceived convenience, E-promotion, brand awareness, and personalization whereas the dependent variable is consumer purchase intention. All the variables are adapted from the previous researcher such as perceived convenience is adapted from Mathew and Soliman (2020) and Duarte *et al*. (2018), E-promotion is adapted from Hanaysha (2018) and Zhu *et al*. (2020), brand awareness is adapted from Hasan and Sohail (2020) and Martins *et al*. (2018), and Sama (2019) and personalization is adapted from Yadav and Rahman (2018) and Liu et al. (2019). The dependent variable; consumer purchase intention is adapted from the prior researcher, Martins *et al*. (2018), Pena-Garcia *et al*. (2020), and Tran (2020), and slight changes are made based on the requirement of this research objective as the independent variable will influence the dependent variable. The primary objective of this study is to examine the influence of digital marketing on consumers' purchase intention in Klang Valley, Malaysia in 2021.

MATERIALS AND METHODS

The current study used a quantitative technique as its method. Based on Hanaysha (2018), quantitative methodology is considered the optimal approach due to its ability to collect data without necessitating extensive skills from a wide range of individuals within the targeted group to complete the questionnaire. Hence, probability sampling methods were applied for the selection of a sample from a population in Klang Valley, Malaysia. A stratified sampling is employed based on the relevant characteristics such as location, age, and intention to use e-commerce. A methodology is deemed appropriate for this study as it encompassed a sample size of 385 participants. Following Krejcie and Morgan (1970), the recommended sample size is 384 for a population of 1,000,000. Therefore, the study distributed 385 questionnaires to fulfill the recommended sample size. The questionnaire employed in this study is self-administered and chosen for its convenience and cost-effectiveness. The measurement items included in the questionnaire were adapted and modified from a past study conducted by Tran *et al.* (2020). The questionnaire comprises three distinct sections (A, B, and C) that are delineated by different features and factors to gather data. Section A is designated to conceal the demographic information of the respondents, including variables such as age, gender, occupation, frequency of daily internet usage on mobile devices, and experience with online

purchasing. Additionally, Section B of the study will serve to obscure the data about the independent factors, while Section C will address the aspect of the dependent variable that demonstrates the relationship between the independent variables. The survey will employ a five-point Likert Scale ranging from 1 (strongly disagree) to 5 (strongly agree) to evaluate participants' responses to the questions. The scale employed in this study serves the purpose of assessing the respondent's level of agreement or disagreement with each statement that forms the basis of the independent and dependent variables (Dewi *et al*., 2020). In addition, employing this scale offers several benefits, including a higher response rate and improved response quality, as well as a reduction in respondent aggravation or frustration respondent (Shareef *et al*., 2019) when completing the provided questionnaire. The participants in this study consisted of working adults residing in the Klang Valley region who use e-commerce platforms. In urban areas, 79.3% of consumers are engaged in e-commerce activities (Malaysian Communications and Multimedia Commission, 2022), therefore, Klang Valley can represent Malaysia in e-commerce activity. The selected respondents were between the ages of 20 and 59. To ensure the validity of the participation criteria, three screening questions will be asked before the respondents can answer the survey questions. For example, the age of respondents; location of respondents; and do you have experience with e-commerce. If the respondents fulfill all the criteria, respondents can click the next page of the question to start answering. If one of the criteria is not fulfilled by respondents, automatically the message will pop up as "Thank you for being interested in this survey, unfortunately, you are not the right respondent for this survey". This study employed a convenience sampling method to choose participants, specifically targeting working people who often use e-commerce platforms. The questionnaires were distributed through an online platform to the target population group. This study adopted a quantitative approach as it is suitable for huge and large data (Hanaysha, 2018). Hence, the present study employed the SmartPLS software to assess the effect of digital marketing on consumers' purchase intention. Before starting the actual data collection, this study conducted a pre-pilot test including a sample of 50 participants residing in the Klang Valley region, ranging in age from 20 to 59 years. A pilot was conducted to verify the inference and to clarify that the source of information and interaction characteristics were successful (Dong *et al*., 2018) before the actual data collection. As suggested by (Mou *et al*., 2019), a pilot study is carried out to ensure the research survey is understandable and the survey items are appropriate.

RESULTS AND DISCUSSION

Measurement model

The first stage of the two-step procedure involves evaluating the measurement model. A systematic PLS evaluation includes the estimation of the variables' reliability and validity using criteria associated with reflective and formative measurement model criteria. The application of the inner path model is justified when the adequacy of the observed latent variables' validity and reliability is considered satisfactory for subsequent analysis. Fig. 2 illustrates the measuring model.

Before doing Confirmatory Factor Analysis (CFA), an initial test is performed to assess the internal consistency of the data. Composite Dependability (CD) and Cronbach's Alpha (CA) are employed to evaluate the internal consistency dependability of the measurement model. CR is a metric that assesses the extent to which a construct is accurately represented by its assigned items, whereas CA is employed to evaluate the dependability of the construct (Cronbach, 1951). A measurement model is considered to have sufficient internal consistency reliability when the Composite Reliability (CR) and the Average Variance Extracted (AVE) of each construct are both greater than the threshold value of 0.7 (Hair *et al*., 2014). Table 1 shows that the CRs of the indicators range from 0.870 to 0.896. Therefore, the findings suggest that the items employed to represent the constructs possess sufficient levels of internal consistency reliability. Convergent Validity pertains to a collection of indications that are presumed to assess the same underlying concept (Kline, 2005). Convergent Validity measures the degree of correlation between items that are expected to represent the same underlying concept. It is often assessed by calculating the Average Extracted Variance (AVE) (Jin *et al*., 2013). Convergent validity is considered acceptable when the constructs have an average variance extracted value of at least 0.5 or higher. All constructs in this study exhibit Average Variance Extracted (AVE) values

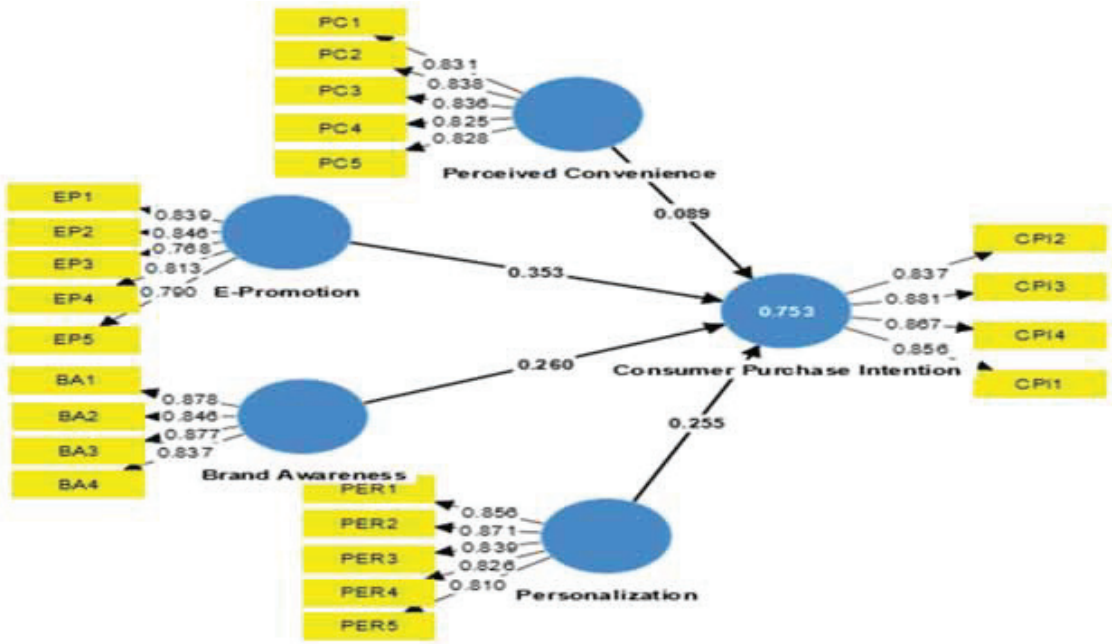

Fig. 2: Measurement model

that range from 0.657 to 0.740. The output as shown in Table 1, denotes that the indicators used for the constructs have exhibited satisfactory convergent validity.

Structural model

Smart PLS is utilized to execute some tests. The subsequent sections will examine the tests employed to evaluate the soundness of the structural models utilized in this work. The structural model's validity is assessed through the use of the coefficient of determination and route coefficients. The Coefficient of Determination (R^2) quantifies the prediction accuracy of the model (Samimi and Nouri, 2023). The R^2 value quantifies the proportion of variability in the dependent variables that can be accounted for by the independent variables (Aravind *et al.* 2016; Cheraghipoor *et al.* 2024). R^2 levels, as defined by Richter *et al.* (2016), may be categorized as considerable, weak, and moderate, corresponding to the values of 0.67, 0.19, and 0.33, respectively. Therefore, R-squared is considered moderate when a small number of external latent variables are responsible for explaining the endogenous latent variable in the inner route model structures, as seen in Table 2. The R^2 changes of 0.751 indicates that with the addition of one interaction term, the R^2 has changed about 75.1%.

The effect size (f2) quantifies the magnitude of influence that a certain construct has on an endogenous construct, which is referred to as the independent variable. When assessing f2, any values below 0.02 are considered negative, meanwhile, values of 0.02, 0.15, and 0.35 are categorized as having positive modest, medium, and large effects, respectively (Cohen, 1988). In Table 3, the results of the effect size denote that all relationships have an effect size between small to large except for Perceived Convenience (PC) which has a negative influence.

The Fornell-Larcker method can identify the construct that has a higher degree of shared variance with its indicators compared to the indicators in other constructs. To achieve this, Fornell and Larcker (1981) suggested that the value of the AVE for each construct needs to be higher than the value of the correlation with the other constructs. The Fornell-Larcker values for each construct are presented in Table 4. The AVE values are displayed in bold and arranged diagonally to facilitate comparisons with correlation values in other constructs, which may

Table 1: Outer loadings

Construct	Items	Loadings	AVE	CR
Perceived Convenience	PC1	0.831	0.692	0.889
	PC2	0.838		
	PC3	0.836		
	PC4	0.825		
	PC5	0.828		
E-Promotion	EP1	0.839	0.657	0.870
	EP2	0.846		
	EP3	0.768		
	EP4	0.813		
	EP5	0.790		
Brand Awareness	BA1	0.878	0.739	0.882
	BA2	0.846		
	BA3	0.877		
	BA4	0.837		
Personalization	PER1	0.856	0.707	0.896
	PER2	0.871		
	PER3	0.839		
	PER4	0.826		
	PER5	0.810		
Consumer Purchase Intention	CPI1	0.856	0.740	0.883
	CPI2	0.837		
	CPI3	0.881		
	CPI4	0.867		

Table 2: Coefficient of determination R^2

	R Square	R Square Adjusted
Std Decision Making	0.753	0.751

Table 3: Assessment of effect size f^2

	Consumer Purchase Intention (CPI)
Perceived Convenience (PC)	0.011
E-Promotion (EP)	0.207
Brand Awareness (BA)	0.064
Personalization (P)	0.063

Table 4: Fornell-Larcker criterion

	Brand Awareness	Consumer Purchase Intention	E-Promotion	Perceived Convenience	Personalization
Brand Awareness	0.86				
Consumer Purchase Intention	0.806	0.86			
E-Promotion	0.749	0.787	0.812		
Perceived Convenience	0.759	0.709	0.637	0.832	
Personalization	0.839	0.795	0.717	0.776	0.841

be made by examining the columns and rows. The study results indicate that all the AVE values are higher than the other construct correlation values, which suggests that there is adequate discriminant validity. The circumstance implies that the constructs utilized in this study are distinct and do not share any common elements with other constructs.

Discriminant Validity refers to the extent to which two conceptually similar concepts may be differentiated from each other. Table 5 demonstrates that the loading of each indication is greater than its other cross-loadings. This demonstrates that the things are organized based on their optimal suitability and simultaneously differentiated from the other elements.

The Heterotrait-Monotrait (HTMT) criteria is an additional approach utilized for evaluating the discriminant validity. If the HTMT value is less than 0.90, it indicates that there is discriminant validity between two reflective notions (Hair et al., 2014). The value range shown in Table 6 is between 0.719 to 0.943.

Overall, Fornell-Lacker, Cross loading and Heterotrait-Monotrait (HTMT) provide evidence for the construct validity. As shown in Tables 2, to 6, all model evaluation criteria have been upheld for measurements of reliability and validity. Overall, the indicators utilized in this study have been verified as suitable and sufficient for application in the structural model. Table 7 sums up all the significant tasting results for the structural model. There are three out of four hypotheses that are met and show significance. Only one hypothesis is not significant.

According to the result, as illustrated in Table

Table 5: Cross loadings

	Perceived Convenience	E-Promotion	Brand Awareness	Personalization	Consumer Purchase Intention
BA1	0.671	0.63	0.878	0.747	0.665
BA2	0.691	0.597	0.846	0.71	0.644
BA3	0.677	0.635	0.877	0.721	0.709
BA4	0.576	0.706	0.837	0.707	0.743
CPI2	0.517	0.674	0.612	0.633	0.837
CPI3	0.619	0.707	0.706	0.689	0.881
CPI4	0.583	0.653	0.665	0.679	0.867
CPI1	0.708	0.675	0.778	0.73	0.856
EP1	0.497	0.839	0.584	0.608	0.668
EP2	0.523	0.846	0.674	0.592	0.654
EP3	0.398	0.768	0.502	0.491	0.564
EP4	0.534	0.813	0.605	0.564	0.636
EP5	0.618	0.79	0.664	0.645	0.666
PC1	0.831	0.489	0.602	0.644	0.559
PC2	0.838	0.548	0.631	0.641	0.604
PC3	0.836	0.518	0.636	0.639	0.571
PC4	0.825	0.55	0.642	0.647	0.581
PC5	0.828	0.54	0.641	0.656	0.628
PER1	0.69	0.636	0.735	0.856	0.701
PER2	0.69	0.575	0.728	0.871	0.652
PER3	0.63	0.58	0.707	0.839	0.63
PER4	0.644	0.613	0.669	0.826	0.7
PER5	0.606	0.605	0.685	0.81	0.652

Table 6: Heterotrait-Monotrait Ratio (HTMT)

	Heterotrait-monotrait ratio (HTMT)
Perceived Convenience -> Brand Awareness	0.858
Perceived Convenience -> E-Promotion	0.719
Perceived Convenience -> Consumer Purchase Intention	0.795
Personalization -> Perceived Convenience	0.869
Personalization -> Brand Awareness	0.943
Personalization -> E-Promotion	0.808
Personalization -> Consumer Purchase Intention	0.89
E-Promotion -> Brand Awareness	0.848
E-Promotion -> Consumer Purchase Intention	0.896
Consumer Purchase Intention -> Brand Awareness	0.906

Table 7: Path Coefficient

	Original sample (O)	Sample mean (M)	Standard Deviation (STDEV)	T-statistics (|O/STDEV|)	P-values	Significance Level
Perceived Convenience -> Consumer Purchase Intention	0.089	0.09	0.054	1.646	0.1	Not Significant
E-Promotion -> Consumer Purchase Intention	0.353	0.35	0.053	6.601	0	Significant
Brand Awareness -> Consumer Purchase Intention	0.26	0.261	0.065	3.975	0	Significant
Personalization -> Consumer Purchase Intention	0.255	0.256	0.061	4.152	0	Significant

7, the result of the path coefficient reveals that E-Promotion (β=6.601, p<0.05), Brand awareness (β=3.975, p<0.05), Personalization (β=4.152, p<0.05) has significant effects over Customer Purchase Intention. However, Perceived Convenience has no significant effects on Purchase Intention (β=1.646, p<0.05). Therefore, the most significant factor ranked first was e-promotion, second was personalization and third was brand awareness.

Discussion

The direct effect of perceived convenience on consumers' purchase intention

The study found that perceived convenience (H1) was not a significant factor influencing consumers' purchase intention in an e-commerce platform in the Klang Valley region. Chowdhury (2023), defines perceived convenience as the advantages connected to consumers' perceptions that online purchasing is more straightforward, has fewer risks, offers a wide selection of products, and is more reasonable and convenient than traditional shopping. Unfortunately, the findings indicate that the participants do not regard perceived convenience as an inherent attribute of the e-commerce platform. This probably is due to their difficulty in accessing and locating desired products as they must spend some time to search and identify desired products. The respondents also stated that they found it challenging to interpret the graphics and content in the product advertisement when seeing it online. The finding of this study supports Duarte *et al*. (2018) that perceived convenience plays

a key role in influencing consumers' decision to buy. In addition, the participants expressed difficulties in accessing and engaging with the seller for additional information and support. According to Jebarajakirthy and Shankar (2021), the provision of post-benefit services by service providers, such as efficient complaint management and accessible support teams, plays a crucial role in motivating customers to utilize online channels. Hence, the effect of perceived convenience on consumer purchase intention is insignificant due to the inconvenience associated with shopping via digital devices. Therefore, it is unable to improve the overall convenience shopping experience for consumers.

The direct effect of e-promotion on consumers' purchase intention

The E-Promotion (H2) was recognized as the significant factor that influences the consumers' purchase intention in an E-Commerce platform. The results of the present study show that respondents are considering various e-promotion methods, such as email promotion, pop-up promotion, and SMS promotions, which capture their attention and influence their online purchase intention. This observation is similar to (Zhu *et al.*, 2020). In addition, this study demonstrates that the digital presentation of seasonal promotions and price deals effectively captured the attention of the respondents, serving as an appealing factor of electronic promotion. This outcome lines up with the previous research conducted by Hanaysha (2018), which highlighted the positive impact of online promotions on consumer purchase intention. In addition, respondents' express excitement and interest in the elements of electronic promotion, such as seasonal promotions or price incentives, including customer coupons, rebates, promo codes, and online store discounts. Previous research has indicated that consumers exhibit price sensitivity when they possess a greater knowledge of promotional activities (Khouja and Liu, 2020). This result is further proved by the present study. This finding indicates that customer purchase intention is influenced by the presence of online promotions among online purchasers. Hence, there exists a notable correlation between E-Promotion and consumers' intention to make a purchase.

The direct effect of brand awareness on consumers' purchase intention

Brand Awareness (H3) was found to be the significant factor influencing the consumers' purchase intention in an E-Commerce platform. In other words, the digital marketing factor, brand awareness was significantly and positively influencing the consumers' purchase intention in an e-commerce platform in Klang Valley. According to the study's findings, consumers who have high levels of brand awareness will be more likely to make a purchase decision. Additionally, they notice and remember the brand or logo that appears on a digital platform, demonstrating their brand awareness. The finding of this study is similar to (Hasan and Sohail, 2020). In addition, the results of this study on brand awareness are similar to prior research indicating that individuals exhibit brand familiarity when they encounter it frequently in online platforms (Martins *et al.*, 2018). Furthermore, these findings corroborate the notion that individuals are more inclined to make purchases of products that are frequently advertised online (Sama, 2019). The significance of a strong brand lies in its ability to develop compelling advertisements that effectively capture the attention of customers, hence fostering brand recognition and awareness among online individuals (Rosmayani and Mardhatillah, 2019). Moreover, the findings indicate that the behavior of respondents are more observable in terms of brand awareness when making digital product purchases. Therefore, the effect of brand awareness on consumers' purchase intention in an e-commerce platform is a significant factor which is consistent with the findings of Hasan and Sohail's (2020).

The direct effect of personalization and consumers' purchase intention

The personalization (H4) of digital marketing factor was found to be a significant factor as it influences the consumers' purchase intention in an e-commerce platform in Klang Valley. Based on the outcomes of this study, it can be inferred that the respondents' priorities are personalization, as they express a preference for products that are tailored to their wants and needs. This study confirms the findings of previous research by Yadav and Rahman (2018), which demonstrated the effectiveness of personalization in meeting the needs and understanding of respondents in digital

marketing. Other than that, respondents agreed that personalization in an e-commerce platform that stores all their preferences and offers extra services with a good prediction of their wants and needs would attract them and affect their purchase intention. This is because personalization provides users with suitable websites to offer them the potential products that they need with similar characteristics. Hence, personalization has a significant relationship with consumers' purchase intention which indicates that prior study findings (Liu Yang *et al*., 2019) are true as personalization attracts customer attention and its increases purchase intention.

Contributions of study

The obtained outcomes of this study extended the existing knowledge base and theoretical development to revalidating the important relationship of elements that impact customer purchase intention. This study provided empirical evidence on the significant factors that influence the consumer purchase intention in an e-commerce platform in Klang Valley, such as perceived convenience, brand awareness, e-promotion, and personalization. This study proved that three factors (i.e., brand awareness, e-promotion, and personalization) play a significant role in the consumer purchase intention in an e-commerce platform in Klang Valley. This study additionally provided practical insights for sellers to enhance their understanding of digital marketing. One of the factors that does not significantly influence consumer purchase intention in an e-commerce platform is perceived convenience. The effect of perceived convenience on consumer purchase intention is negligible, as it results in a cumbersome shopping experience when using digital devices. The graphics and text presented lack convenience for customers in accessing the necessary information. Hence, it is imperative for sellers to offer customers a seamless shopping experience, as the perceived convenience holds significant importance. Customers are inclined towards utilizing e-commerce platforms due to the benefits it offers, such as the capability to swiftly compare prices and gather information, thereby presenting a straightforward and convenient experience. The lack of user-friendliness in digital content marketing is likely to hinder customers' willingness to employ it for product and service selection within the e-commerce sector. Additionally, it is imperative for an e-commerce platform to consistently offer regular e-promotion bargains on its items and services. E-promotions have the potential to facilitate and encourage consumers to engage in product switching or trial experiences with alternative offerings. E-mails and pop-up promotions help to attract and increase the interest of consumers which in return influence their purchase intention. E-promotion is a significant component in the marketing mix strategy for capturing new consumers and motivating existing customers to inform and persuade the consumer to buy or rebuy the company's products and services, as well as seek customers to transfer brands from one to another. Hence, the sellers should consider and increase e-promotional deals to attract new and existing consumers. Subsequently, brand awareness helps a consumer to recognize a product just by its name. A product that has a brand and is well-known by consumers is more likely to influence consumer purchase intention. Hence, products that are sold in an e-commerce platform should create an awareness and stand out from other products in the market. Building brand recognition is a crucial step in advertising a new product or revitalizing an existing one. In general, creating brand awareness produces a collection of characteristics that set the product apart from its competitors. Furthermore, it is crucial for businesses to establish brand awareness as a fundamental element for their survival and success. This can be achieved by engaging with new and existing customers through social media brand pages, with the aim of enhancing brand awareness and brand image. Ultimately, this will lead to an increase in product sales on an e-commerce platform. Apart from that, an e-commerce platform should also personalize their digital marketing strategies to attract prospective customers to shop using e-commerce platform. To influence a consumer purchase intention, the e-commerce platform should understand the needs and wants of the consumers and customize its home page for each user based on their search history and the products that they have browsed previously. The primary objective of an e-commerce marketing platform is that the material that is promoted is suited to the consumers' preferences. In addition, the marketing department of an e-commerce platform must engage in data mining by analyzing customer activities such as browsing, searching, purchasing, reviewing, and collecting. This analysis allows for the prediction and examination of consumer demand for goods and services, as well as the provision of personalized products and services. This will aid in exerting influence and enticing a greater number of new and current users.

CONCLUSION

Finally, this research analyzed the factors of digital marketing (1) Perceived Convenience, (2) E-Promotion, (3) Brand Awareness, and (4) Personalization that influences the consumers' purchase intention in an E-commerce platform in Klang Valley. The findings of this study indicate that the first research question examined the influence of perceived convenience (H1) on customer purchase intention. The results revealed that perceived convenience does not significantly assist customers in terms of e-commerce. Customers' perception of e-commerce does not improve the simplicity of customers ' shopping activity, thereby not impacting their purchase intention. For example, customers are unable to shop at anytime and anywhere they want; it is not easy to access and find any product that they need; it is not easy to reach and interact with the seller; graphics and text in the product advertisement are not easy to understand. This study provides evidence that e-promotion (H2) has an impact on customer purchase intention. E-promotion elements such as customers receiving email; message promotions; pop-up promotions; getting seasonal promotions and price deals digitally attracted their attention as well as shopping decisions. Consumers tend to be price sensitive when promotional activities are known to take place because it is much cheaper. Concerning the third research inquiry, the findings of this study indicate that brand awareness (H3) positively influences customer purchase intention. Customers' purchase intention is affected when brand names are frequently advertised through digital platforms. For example, consumers can recognize and recall the brand characters well; customers tend to be familiar with and aware of a particular brand's products and services that are available in the market; and customers tend to trust the brand's ability. As for the final research question, consumer purchase intention was also influenced by personalization (H4) because the action of digital marketing facilitates personalized to meet the consumers' requirements. For example, personalization content makes purchase recommendations as per customers' requirements; digital marketing facilitates personalized information search directly to customers' interest and buying behavior that predicts what customers might want when surfing the internet. The study has two limitations. Firstly, it just concentrates on examining the direct relationship between the proposed variables. Secondly, it does not consider any specific e-commerce platform. However, the limitations of the study have yielded two recommendations for future research. Firstly, it is recommended to incorporate a third variable, such as a moderator or mediator, to explore the indirect relationship further. Secondly, it is suggested to concentrate on specific e-commerce platforms to gain a more comprehensive understanding of the subject matter. Consequently, the replication and extension of this study will facilitate the examination of the generalizability of the findings, thereby establishing a robust basis for the external validation of the proposed framework in this investigation, aiming to enhance comprehension of consumer purchasing intention within an e-commerce platform. The obtained findings of this study were expected to benefit all businesses including Micro, Small, and Medium Enterprises (MSMEs) that form the backbone of Malaysia's economy, especially in their evaluation of the factors that influence the consumer purchase intention in an e-commerce platform. In general, this study has enhanced the business's comprehension of digital marketing, thereby contributing to the economic and social activities that involve the production and use of digital technology by individuals and businesses towards Malaysia's economic growth objectives by the year 2030 in My Digital Economic Blueprint of implementation.

AUTHOR CONTRIBUTIONS

Aeshah Mohd Ali, Sharmini Manogaran, Kausalya Selvarajan, Nur Ilyana Ismarau Tajuddin and Uma Thevi Munikrishnan performed the literature review, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. Aeshah Mohd Ali, Sharmini Manogaran, Kausalya Selvarajan compiled the data and manuscript preparation. Aeshah Mohd Ali, Sharmini Manogaran, Kausalya Selvarajan, and Mohd Remie Mohd Johan conceived the idea and reviewed the manuscript.

ACKNOWLEDGEMENT

The authors would like to express their thankfulness to all the editors and reviewers who offered insightful feedback for improvement on this manuscript.

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, falsification, double publication, submission, and redundancy, have been entirely witnessed by the authors.

OPEN ACCESS

PUBLISHER'S NOTE

Tehran Urban Planning and Research Centre remains neutral with regard to jurisdictional claims in published maps and institutional afflictions.

ABBREVIATIONS

AVE	Average Extracted Variance
β	Statistical test that compares the means of two samples
BA	Brand Awareness
CA	Cronbach's Alpha
CFA	Confirmatory Factor Analysis
CPI	Consumer Purchase Intention
CR	Composite Reliability
DV	Dependent Variable
EP	E-Promotion
f^2	effect size
HTMT	Heterotrait-Monotrait Ratio
H_1	Hypothesis one
H_2	Hypothesis two
H_3	Hypothesis three
H_4	Hypothesis four
IV	Independent variable
M	Mean
O	Original sample
P	Personalization
PC	Perceived Convenience
P Values	Probability Value
R^2	Coefficient of determination
SmartPLS	Smart partial least squares
SME	Small and Medium Enterprise
S-O-R	Stimulus-Organisms-Response
STDEV	Standard Deviation

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HOW TO CITE THIS ARTICLE

Mohd Ali, A.; Manogaran, S.; Selvarajan, K.; Ismarau Tajuddin, N.I.; Mohd Johan, M.R.; Munikrishnan, U., (2024). Digital marketing: consumers' purchase intention towards e-commerce platform for urban region. Int. J. Hum. Capital Urban Manage., 9(3): 473-488.

DOI: 10.22034/IJHCUM.2024.03.08

URL: https://www.ijhcum.net/article_711371.html

Int. J. Hum. Capital Urban Manage., 9(3): 489-508, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Analyzing barriers in peri-urban land development for informed policymaking

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ARTICLE INFO

Article History:
Received 20 March 2024
Revised 15 May 2024
Accepted 28 June 2024

Keywords:
Barriers
DEMATEL ISM approach
Land development
Policymaking
Urban management

ABSTRACT

BACKGROUND AND OBJECTIVES: Peri-urban land development is crucial to achieving the UN Sustainable Development Goal of equitable and sustainable urban areas. Fair land, infrastructure, and resource management improves land management services and reduces social and economic inequities. However, the peri-urban land management system has contributed to unequal rapid urbanization in neighboring regions. This study examines the complex relationships between peri-urban land development barriers in India. The goal is to understand how these barriers induce unequal urbanization transcending the city, resulting in uncontrolled growth, urban sprawl, and inadequate services in peri-urban areas. The main goal is to improve decision-making and promote fair peri-urban growth in Indian cities using a multi-criteria decision-making tool. This application gives experts a new perspective on peri-urban issues.

METHODS: A questionnaire-based survey was conducted by 122 planners and academicians from north Indian cities using snowball sampling techniques. The study collects expert perspectives to create a causal map, using the DEMATEL ISM method, classifying these barriers as "determinants or causes," "dependent barriers," "independent barriers," and "effects," presenting a new perspective on peri-urban development complexity. that depicts these roadblocks and highlights the most significant drivers impeding peri-urban land development.

FINDINGS: Findings revealed four interdependent challenges as the leading 'causes' based on DEMATEL Weight; Imprecise spatial policies with 0.10119, undemarcated land boundaries with 0.10082, weak institutions with 0.10003, and absence of planning regulations with 0.09945 weight. Within these barriers, addressing the governance capability and spatial policies would have a beneficial cascading effect on catering to other challenges. Findings have valuable insights for policymakers, aiding in the formulation and prioritization of effective policies and resource allocation.

CONCLUSION: This study extensive analysis of causal linkages among Indian city peri-urban land development challenges. Beyond identifying barriers, it explains their causes, interdependencies, and hierarchical links. This study's holistic approach to peri-urban development issues and inventive barrier categorization and prioritization make it distinctive.

DOI: 10.22034/IJHCUM.2024.03.09

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
61	3	11

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

Rapid urbanization has extended cities beyond their traditional borders, creating vast built-up areas and transforming agricultural land. These changes, caused by real estate market dynamics and regulatory interventions like Special Economic Zones (SEZ) and new townships, stress natural resources and risk conflict (Narain, 2009; Ahani and Dadashpoor, 2021b). Peri-urban regions, straddling urban and rural areas, are characterized by agricultural activities, informal settlements, and rapid urban growth (López-Goyburu and García-Montero, 2018; Ahani and Dadashpoor, 2021b; Cattivelli, 2021). Peri-urban areas may be the epicenter of global urbanization, with the greatest prospects and concerns (Allen, 2003). Over time, peri-urban areas have evolved from an intangible idea to a broadened region that competes for land. Although perI-urban areas can provide infrastructural needs, relieving urban centers of the effects of fast expansion, it results in disorganized and fragmented development, urban sprawl, and inadequate critical services (Wolff, Mdemu, and Lakes, 2021). Therefore, the conflicting development is harming the region's socio-environmental framework. Additionally, peri-urban land development is critical for attaining equitable development as outlined in the United Nations Sustainable Development Goal 11. It emphasizes effective land management practices to ensure equitable access to land, infrastructure, and resources, which address social and economic imbalances within communities (Follmann, Hartmann, and Dannenberg, 2018). Many studies have identified urban phases characterized by variable intensity of growth patterns and reflecting distinct socioeconomic contexts with inherent variability in development (Ma *et al.*, 2018). The peri-urban land development process in Indian cities is crucial for several reasons. Metropolitan and significant urban agglomerations in India are projected to add 416 million people by 2050 and built-up area growth is far its peri-urban hinterlands than in municipalities (Cattivelli, 2021). Inefficient peri-urban land management has produced an imbalance in preventing city expansion into outlying areas (Dutta, 2012). Due to legislative issues, Urban Local Bodies (ULBs) cannot integrate regional and master plans for peri-urban expansion and analyze transformation (Aijaz, 2019). The top-down administrative approach also limits land intervention frameworks due to a lack of knowledge of the urban-rural split and its fluid planning process (Aijaz, 2019; Follmann *et al.*, 2023). The numerous barriers impeding land development, especially in the uncertain boundaries of periphery or peri-urban areas, are exacerbated by the ever-changing characteristics of the land, which undergoes transitions from rural to urban environments due to several factors (Dadashpoor and Malekzadeh, 2020). The issues encompass a wide range, such as ambiguous demarcation of peri-urban regions (Mortoja, Yigitcanlar and Mayere, 2020), the existence of numerous overlapping institutions (Marshall and Dolley, 2019), disputes over land ownership, non-compliant land development methods, lack of territorial planning tools (Wolff, Mdemu and Lakes, 2021), informality of land ownership, influences from neo-liberal forces, and the phenomenon of gentrification (Akaateba, 2019), lack of unified data, the disregard for decision sciences for land allocation (Žlender, 2021), the absence of explicit regulations and guidelines for transitioning territories, and a planning intervention that frequently disregards regional and local contexts (Nuhu, 2019), adhering to a standardized approach in all peripheral regions. These barriers collectively lead to a fragmented, disorganized, and unsustainable peri-urban landscape. Resolving these issues becomes imperative to achieve a coordinated, equitable, and environmentally sustainable urban expansion. The objective further aligns with the broader goals of fostering resilient and effective urban management practices. Therefore, peri-urban regions in Indian cities suffer an array of land development barriers, and there is a substantial dearth of understanding about the causal-effect links between these barriers (Follmann *et al.*, 2023). The complexity of peri-urban communities, frequently disregarded in urban-rural classifications, presents several problems and hurdles to equitable and sustainable development. Cities need land for homes, jobs, and economic activities, requiring efficient land management to maximize resource use (Adam, 2014). One must comprehend local government regulations, legislation, and institutional competence to identify and handle peri-urban regions most vulnerable to uncontrolled growth. Urban planning standards, efficient laws, and inclusive governance are needed to monitor India's

urban expansion and promote fair, ecologically sustainable land usage (Sareen and Haque, 2023a). The expansion of urban limits, frequently with government aid, is complex and connected with land use planning and governance, especially Master Plans. Peri-urban periphery, historically managed by rural authorities, has presented particular issues in India. Peri-urban areas lack governance because water delivery, sanitation, and waste collection are now urban responsibilities (Aijaz, 2019). Peri-urban areas, influenced by urban development, attract industries, SEZs, and IT parks due to location and lower land costs. This prevalent tendency in large Indian cities is seen in increased employment and migration. These transitional areas have significant population increase, while the city core stagnates, indicating the diverse impact of government policy on urban expansion dynamics (Jain and Korzhenevych, 2020). In India, land governance is hierarchical and involves multiple government and administrative levels. The State Government, which sets the policy framework, has complex power relationships with local governments, resulting in ineffective land management in many Indian towns (Jain, 2018). Land governance differences emerged when the focus shifted from urban to peri-urban regions. Municipal corporations and local planning organizations handle urban land-use planning and infrastructure. Peri-urban areas are managed by the revenue department and local panchayats. The limited capability and resources of these agencies sometimes lead to informal development, encroachment, and land usage conflicts (Mondal and Banerjee, 2021). Common land interventions including urban planning schemes, land pooling, and land acquisition lacked strategic planning and often faced local resistance. Despite their widespread use, these interventions have been condemned for their lack of transparency, accountability, and community participation, which has hurt the affected people's livelihoods and rights (Gomes *et al.*, 2023). Without a regulatory framework for transitioning areas, peri-urban land management is still seen as informal and disorganized (Follmann, Hartmann, and Dannenberg, 2018). The lack of a comprehensive national land-use strategy in India leads to a fragmented and unpredictable land-use process, impeding efficient planning and sustainable development (Shaw and Das, 2018). simultaneous existence of multiple land development strategies, prompted by economic, sociological, and technological expectations, complicates land ownership, usage rights, and income and resource distribution (Marshall and Dolley, 2019). The complex situation at hand requires a thorough examination from the viewpoint of urban planning and land resource management, which is lacking in the existing literature. Also, it becomes essential to understand the complex nature of rural-urban transition in the peri-urban landscape from the governance perspective as the government and decision-making bodies exert considerable influence in pre-urban land development, owing to the transitional characteristics of these places. In contrast to firmly established urban environments, peri-urban regions frequently see swift transformations as they transition from rural to urban. In peri-urban regions, where the process of transitioning from rural to urban areas is still in progress, the government assumes a pivotal role in establishing the regulatory structure, guaranteeing adherence to regulations, and providing guidance for the general trajectory of development (Follmann *et al.*, 2023). Decision-making entities play a pivotal role in defining pre-urban land development, encompassing many stakeholders such as urban local bodies, development authorities, and municipal corporations. These organizations are responsible for the formulation of policies, the approval of development plans, and the supervision of project implementation, thereby exerting a substantial influence on the spatial and structural changes occurring in peri-urban areas. In later stages of urban development, the participation of additional players, such as private developers, community groups, or non-governmental organizations, may become increasingly prominent. However, during the earliest phases, a robust regulatory and planning framework is typically necessary. The establishment and implementation of this framework are commonly undertaken by governmental entities and policymakers to facilitate a synchronized and regulated shift from rural to urban environments. To achieve the mentioned objectives, the authors have conducted a questionnaire-based study by circulating on an online Google form during April 2023 to the planning domain experts. Current practices and policy information gap stifles effective planning and decision-making. To overcome the knowledge gap, the study's objectives are to i) thoroughly examine

Table 1: List of barriers

Challenge	Description
B1	Peri-urban area demarcation is ambiguous
B2	Insufficient development of skills and abilities within institutions(Urban local bodies/ Government Authorities)
B3	Overlapping and multiple institutes (Urban local bodies/ Government Authorities) leading to conflict in land intervention
B4	Notable absence of effective spatial policy-making and a comprehensive approach to territorial governance
B5	For the peri-urban area, there are no comprehensive planning regulations or benchmarking
B6	Lack of cadastral data for spatial assessment of Land,
B7	Lack of Limitation on metropolitan overgrowth in the periphery
B8	Insufficient policies, plans, methods, and evaluations to curb unauthorized exploitation of natural and agricultural resources
B9	Lack of studies evaluating the implementation and adherence of plans after their execution
B10	Exhibit high levels of informality in land use and tenure arrangements
Present study	The study will rank the barriers to understanding the relative significance of these above challenges by employing the MCDM technique on experts' responses to inform the policymakers for resource allocation and targeted intervention.

the root causes and linkages among the identified barriers through a structured methodology to gain a full understanding of the intricate factors involved in peri-urban land development and ii) To present the hierarchical structure of the identified barriers and determine the ones with the most influence, providing valuable insights into the areas where interventions can yield the most substantial effects. The current study has been carried out in the cities of north Indian states using a questionnaire-based survey sent through an online Google form in April 2023 to specialists in the field of planning.

Identification of barriers

Literature shortlisting was done systematically using inclusion and exclusion criteria to compile the significant peri-urban land development barriers for the experts to review during April 2023. A total of 167 articles were collected from Web of Science and Scopus databases using keywords: *peri-urbanization* OR *peri-urban development* OR *peri-urban planning*, AND, *land development* OR *land management* OR *intervention* in title, abstract, and keywords of the articles. The research's goal of studying and analyzing peri-urban development was best described by these keywords in conjunction with the associated land intervention with the usage AND/OR with selected words from boolean logic. Additional inclusion criteria were the type of articles published, i.e. only Journal articles published in the *English language were included*. These shortlisted articles were filtered by *publication date.* i.e. articles published during *2013-2023* were included to cater to recent and relevant issues arising in the research domain. The step yielded 71 articles which were further screened based on the analysis of *explicit mention of the challenge or barrier* faced in the study. Based on these criteria, 24 articles were included in the review. The selected papers were further manually analyzed by the authors for the identification of the challenges in Indian cities or similar cities of developing nations. The authors selected 10 challenges which were discussed in the multiple papers as illustrated in Table 1. The experts in the questionnaire further analyze these challenges to understand the relative significance, and further, statistical analysis helps In identifying the cause-effect relationship and hierarchical structure of this complex web of challenges. Further, the selected 24 articles for comprehension of the issues they present are illustrated in Table 2.

Issues in peri-urban land development

Peri-urban development research shows significant social and environmental differences between core cities and peri-urban areas. The lack of land development and urban growth control in local planning is the main cause of this gap (Jain, Korzhenevych, and Sridharan, 2019; Salem, Tsurusaki, and Divigalpitiya, 2020). Decision sciences and methods to prioritize lands (Dutta, 2012; Honeck *et al.*, 2020) and solve inequities in peri-urban regions (Mondal and Banerjee, 2021) are still unclear and have ambiguous approaches. Peri-urban regions lack well-planned and ordered spatial structures, resulting in uncontrolled urban expansion and large city layout modifications (Long *et al.*, 2020). Uncontrolled growth causes disorganized settings, with peri-urban residential complexes covering more space than the city center (Marshall and Dolley, 2019).

Table 2: List of Barriers identified in the literature. (**O**= Observed/Identified)

S.No.	Sources	Barriers									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
1.	(Adam, 2015)	O	O		O			O		O	O
2.	(Hedblom, Andersson and Borgström, 2017)		O	O		O	O	O	O	O	
3.	(Dutta and Roy, 2017)					O					O
4.	(Arif and Gupta, 2018)	O		O				O			
5.	(Shaw and Das, 2018)				O	O				O	
6.	(Follmann, Hartmann and Dannenberg, 2018)	O	O				O	O	O		
7,	(Jain, Korzhenevych and Sridharan, 2019)			O		O					O
8.	(Nuhu, 2019)		O		O				O	O	
9.	(Marshall and Dolley, 2019)	O					O	O			O
10.	(Aijaz, 2019)			O		O			O	O	
11.	(Jain, 2019)	O		O			O			O	
12.	(Long *et al.*, 2020)		O		O	O		O			
13.	(Mondal and Sen, 2020)	O			O			O			O
14.	(Hussnain et al., 2020)		O					O	O		
	(Wubie, de Vries and Alemie, 2021)			O	O	O				O	O
16.	(Wolff, Mdemu, and Lakes, 2021)		O			O	O		O		
17.	(Ahani and Dadashpoor, 2021a)			O				O		O	
18.	(Chettry, 2022)	O	O		O						O
19.	(Mohammadi-Hamidi *et al.*, 2022)		O		O		O				O
20.	(Kurnia *et al.*, 2022)	O		O		O				O	
21.	(Seifollahi-Aghmiuni *et al.*, 2022)		O				O	O	O	O	O
22.	(Sahana *et al.*, 2023)	O			O	O	O				
23.	(Karakadzai *et al.*, 2023)			O				O		O	O
24.	(Follmann *et al.*, 2023)		O	O		O			O		O

This uncontrolled proliferation shows the scope and complexity of urban transition in peri-urban areas and inefficient decision-making. Land ownership, usage, and value disputes are common, owing to issues such as ambiguous property rights and conflicting land uses (Dutta, 2012). The lack of transparent land governance and participatory decision-making procedures exacerbates these tensions. Complex networks of overlapping urban local bodies make defining peri-urban region boundaries challenging, particularly in the face of fast development(Wubie, de Vries, and Alemie, 2020). In peri-urban regions, a lack of knowledge about cadastral data, land records, taxation, demography, land sub-divisions, and land use changes impedes decision-making (Simon, McGregor, and Thompson, 2006; Dadashpoor and Ahani, 2019). Due to a lack of understanding, the decision-making process for land development in peri-urban regions is frequently insufficient. Existing classifications frequently ignore the intricacies that

exist outside the classic rural-urban distinction (Jain and Korzhenevych, 2020; Gottero, Cassatella, and Larcher, 2021). The master plans of urban local bodies (ULBs) frequently ignore crucial variables such as carrying capacity, available resources, and the preservation of local agriculture and resources, resulting in inequities in the advantages of urbanization(Aijaz, 2019). Furthermore, due to a lack of key tools and capabilities, local self-government organizations, particularly in Indian cities, struggle to adapt to the difficulties of urbanization (Aijaz, 2019; Jain, 2019). Land development regulation in peri-urban settings is hampered by rapid changes in open spaces, which result in environmental deterioration (Imbrenda *et al.*, 2021). This degradation involves an unequal distribution of biological traits, which jeopardizes the region's carrying capacity and land suitability (Imbrenda *et al.*, 2021). As a result, peri-urban landscapes are more valued for their immediate financial rewards rather than their agricultural relevance, resulting in spatial changes resembling informal settlements (Ma *et al.*, 2018). Another problem is territorial governance since the notion that all peri-urban regions are the same has negative effects on spatial management and policy (Gonçalves, Gomes, and Ezequiel, 2017). Without a spatial approach to policymaking, managing peri-urban regions across supra-territorial boundaries becomes difficult (Cattivelli, 2021; Gottero, Cassatella, and Larcher, 2021). In India, model guidelines for the development of peri-urban areas were proposed by the Ministry of Housing and Urban Affairs for selected 20 cities across the nation in 2018. However, the guidelines mention the process for the phases-wise development, but approval, management, and planning are in the jurisdiction of the urban local body and do not give insights into dealing with the development. Additionally, spatial perspective is frequently ignored, resulting in plans that fail to recognize the multifunctionality of peri-urban interfaces and their links to neighboring urban and rural regions (Mondal and Sen, 2020). Research gaps in peri-urban land development are discussed in the following Table 3. Furthermore, the existing practices and lack of policy information hinder the ability to plan and make effective decisions. The study aims to address the lack of knowledge by conducting a comprehensive analysis of the underlying causes and connections between the identified challenges using a systematic approach. This will enable a thorough understanding of the complex factors associated with peri-urban land development. Additionally, the study seeks to present the hierarchical arrangement of the identified barriers and identify the ones with the greatest impact, thereby offering valuable insights into the areas where interventions can have the most significant outcomes.

Table 3: Identified research gaps

Sources	Key Research Gap(s)
(Sareen and Haque, 2023b)	In developing cities with no conventional planning regulations, peri-urban gentrification, and land management are understudied, hindering evidence-based decision-making.
(Wubie, de Vries and Alemie, 2021)	Need for a well-designed framework for intervening in peri-urban land areas and precise institutional arrangements. Validating and refining the peri-urban land management approach requires empirical effort.
(Owino *et al.*, 2021)	A limited number of studies thoroughly examine the processes of land use change and spatial arrangements in peri-urban areas.
(Gottero, Cassatella and Larcher, 2021)	Emphasis on developing strategic spatial planning at the local level, considering local concerns and variables.
(Ahani and Dadashpoor, 2021b)	Need to study the implementation of strategic measures in developing countries empirically.
(Arif and Gupta, 2018; Jain and Korzhenevych, 2020)	Lack of understanding regarding the efficacy of land interventions in peri-urban areas in India.
(Jones *et al.*, 2019)	Significance of examining not only the institutional framework governing land access but also motivations and perspectives of individuals towards governance systems.
(Nuhu, 2019)	Additional research is needed to explore the connection between rising insecurity and land conflict in peri-urban regions.
(Owino *et al.*, 2021)	A limited number of studies thoroughly examine the processes of land use change and the spatial arrangements in peri-urban areas.

MATERIALS AND METHODS

The study seeks to understand the governance challenges that hinder peri-urban development, as it is crucial to consider the opinions of sector workers to inform decision-making by addressing peri-urban land development concerns like policy-making, planning strategies, implementation, geographic scale issues, etc. A multi-criteria decision-making (MCDM) tool is essential for solving complicated problems since it evaluates numerous criteria at once. MCDM tools provide a structured framework for assessing and solving complex issues with multiple aspects and barriers. Systematic methods help decompose complicated issues into manageable parts, supporting a disciplined approach to prioritizing peri-urban growth challenges. MCDM technologies also reduce subjectivity, promoting objective decision-making. These techniques ensure that issues are addressed based on their impact and importance rather than subjective impressions by giving a quantitative foundation. The authors used DEMATEL ISM (Decision-Making Trial and Evaluation Laboratory and Interpretive Structural Modelling) to analyze data from their questionnaire-based study on Indian city peri-urban land development challenges. We chose DEMATEL ISM because of its outstanding MCDM approaches for peri-urban land development in Indian towns. Unlike alternative methods, DEMATEL ISM excels in its ability to analyze and visualize casual correlations between criteria or factors, in this case, barriers, offering a comprehensive view of the interdependencies and cause-and-effect relationships in prioritizing obstacles based on their impact, enhancing the decision-making efficacy (Chuang *et al.*, 2013). This provides a complete view of peri-urban development issues' interdependencies and cause-and-effect relationships. The hierarchical perspective provided with this approach helps policymakers prioritize for maximum impact (Chuang *et al.*, 2013). Also, the generated causal maps are easy to interpret, enabling the translation of study findings into policy ideas and, thus, improving real-world decision-making. DEMATEL ISM helps prioritize urgent issues when used in barrier identification studies (Tayebi *et al.*, 2023).

Statistics

In DEMATEL's first step, a questionnaire survey is produced using the mentioned barriers in Table 1. The experts used Satty's five-point integer scale to rate each barrier's impact on another in the questionnaire. The acquired data was used in DEMATEL modeling. The DEMATEL shows causal relationships, weights, and rankings by categorizing components into cause-and-effect categories. In the second stage, DEMATEL cause-and-effect linkages are supplied into ISM modeling. The cause-and-effect linkages determined the directions of the relationships between the components that helped convert DEMATEL to ISM. According to their driving and reliant abilities, DEMATEL ISM separated barriers into four groups: cause, dependent, independent, and effects. The analytical procedure involves establishing an initial or average direct relation matrix, normalizing it, calculating the total relation matrix, and filtering out inconsequential values with a threshold. Total relation matrix row-wise and column-wise sums define barrier prominence and interdependency. DEMATEL weights influence barrier significance. Next, ISM creates contextual barriers and Initial and Final Reachability Matrices. Transitivity checks confirm linkages and hierarchical structure exposes barrier interdependencies and causal links. The causal and interpretive structures from DEMATEL and ISM were used to create an integrated DEMATEL-ISM model. The following subsections describe DEMATEL and ISM modeling procedures and stages.

Data collection methods

A survey appraised peri-urban land development barriers using Satty's five-point rating technique (Tayebi et al., 2023) as illustrated in Table 4. To gain a comprehensive understanding of peri-urban development, 122 experts from Jammu and Kashmir, Himachal Pradesh, Punjab, Uttarakhand, Haryana, Delhi, Rajasthan, and Uttar Pradesh and Bihar, shown in Fig. 1, 83 experts from planning, educational, and research institutes, and 39 planning professionals, including architects, planners, and program managers, were sent a Google form questionnaire with closed-ended questions. We collected data in April 2023. A maximum of 89 of 122 replies were MCDM-analyzed. Incomplete questionnaire responses were removed to maintain data accuracy. Experts from ULBs, such as Development Authorities, Municipal Corporations, and Planning Educational Institutions, were chosen since they make land development decisions. The online poll used Snowball Sampling to select

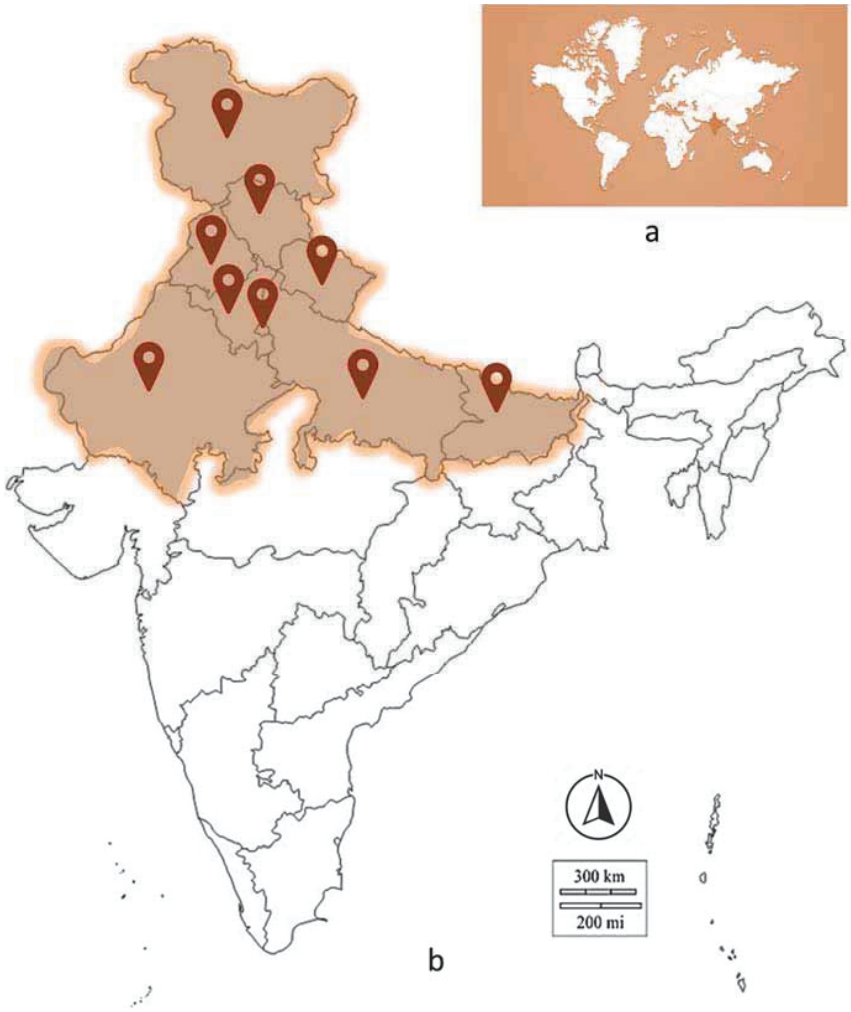

Fig. 1: a. Key map of the World. b.Map showing the states of India from which the experts are selected

Table 4: Lingual term in Salty's scale

Lingual options	Response
Not influential at all	0
Less influential	1
Moderately influential	2
Influential	3
Very influential	4

respondents. Snowball sampling employed peri-urban land development experts' knowledge. These professionals view regional issues holistically. Scholars use snowball sampling to reach specialists not in public databases. Experts participate more, increasing response rates due to their wide professional networks. Snowball sampling accommodates field limits and provides significant data. There is no full

list of peri-urban land development specialists on any portal. Hence, a more rational procedure was needed to choose respondents.

Conventional sampling methods may encounter challenges in clarifying the dynamics of peri-urban land expansion. The preference for cities situated in North India stems from the fact that the difficulties related to land development differ across different regions. To enhance the scope of the study through comparative analysis with other states or cities in the region, a specific focus has been placed on cities located in North India. Geography, culture, and administration pose unique dynamics. The systematic collection of data ensures that the results of the study may be effectively applied to real-world situations

Data reliability

The Cronbach's Alpha coefficient, which gauges the internal consistency of survey data, was used to assess the obtained data for reliability and inconsistencies. The internal consistency of the 89 participants' responses was evaluated using Cronbach's Alpha Value (α) to assess the validity of the information obtained from the questionnaire-based survey employed in this study as discussed using Eq. 1 (Khan *et al.*, 2023).

$$\alpha = \frac{C}{C-1} \times \left(1 - \frac{\sum_{i=1}^{c} \sigma_x^2}{\sigma_y^2} \right) \quad (1)$$

where C denotes the number of challenges (or barriers), σ_x^2 denotes the variance in the scores given to each challenge, σ_y^2 denotes the variance in the total sum of scores given by each participant.The α value obtained in the survey is 0.83 which is greater than 0.7, hence the collected data can be considered reliable for analysis.

Description of the modified DEMATEL ISM analysis procedure

DEMATEL-ISM is a Multi-Criteria Decision Making (MCDM) framework that is used to investigate the cause-effect interrelationship of different criteria. The ISM and DEMATEL have numerous commonalities, including their shared interest in examining the causal relationship between various criteria (Kumar and Dixit, 2018). Since both the ISM and the DEMATEL techniques are potent and useful tools that support the decision-making group, this is the major benefit of the combined approach (Tayebi *et al.*, 2023, Noor *et al.*, 2024).

DEMATEL groups barriers into cause-and-effect categories to identify hierarchically structured solutions. Following are the steps for performing DEMATEL analysis:

Step 1: To incorporate all the responses from n respondents, the initial or average direct relation matrix 'Xij' is developed by using Eq. 2 (Noor *et al.*, 2024):

$$X_{ij}^{*} = \frac{\sum x_{ijk}}{n} \quad (2)$$

where *x* corresponds to the response by participant *k* on the influence of barrier *i* on barrier *j* and *n* is the total number of participants in the survey.

Step 2: This demonstrates the normalization of the average response matrix using Eq. 3 (Noor *et al.*, 2024):

$$X_n = \frac{\mathrm{X}}{max\left(\sum x_{ij}\right)} \quad (3)$$

Step 3: In this step, Total Relation Matrix has been calculated using Eq. 4 (Noor *et al.*, 2024):

$$T = X_n \times \left(I - Xn\right)^{-1} \quad (4)$$

Step 4: Furthermore, to clarify the interrelationship among problems and maintain the problem's complexity manageable, a threshold level 't' was selected to filter out the inconsequential values from matrix 'd' by using Eq. 5 (Noor *et al.*, 2024). The issues that have an impact on the matrix d that exceeds the cutoff value are those that will be subjected to additional analysis

$$t = mean\left(d_i\right) \quad (5)$$

Step 5: The row-wise (D) and column-wise (R) sums of the total relation matrix are used to determine the prominence and interdependency of barriers, as illustrated in Eqs. 6 and 7 (Noor *et al.*, 2024):

$$D = \sum_{i=0}^{n} T_{ij} \quad (6)$$

$$R = \sum_{j=0}^{n} T_{ij} \quad (7)$$

Step 6: The row-wise sum and column-wise sum of the total relation matrix are added to determine the prominence of the barriers, and these same sums are subtracted to determine the relationship value using Eqs. 8 and 9 (Noor *et al.*, 2024):

$$Prominence = D + R \quad (8)$$

$$Relation = D - R \quad (9)$$

Eq. 10 (Noor *et al.*, 2024) has been used to calculate the DEMATEL weight:

$$DEMATEL\,Weight = \frac{(D+R)_i}{\acute{O}(D+R)_i} \quad (10)$$

The ISM technique consists of the following steps as used in previous studies (Chauhan, Singh and Jharkharia, 2018; Khan *et al.*, 2023; Tayebi *et al.*, 2023): In the first step, ten different barriers are considered. In the second step, a contextual relationship between the barriers is generated using DEMATEL, based on the purpose of the research. The average response matrix from DEMATEL analysis is used to create the Initial Reachability Matrix in the third stage, depending on how the barriers "B1" and "B2" interact with one another. In the fourth stage, the Final Reachability Matrix is generated from the Initial Reachability Matrix and checked for transitivity (Tayebi *et al.*, 2023) The ISM's key concept is that the relationships between the barriers are transitive. E.g. if barrier B1 has a strong association with barrier B2, and B2 has a strong association with B3, then B1 is also strongly associated with B3; It implies using Eq. 11 (Noor *et al.*, 2024):

$$if\ IM_{ik} = 1\ \&\ IM_{kj} = 1; then\ FRM_{ij} = IM_{ij} \quad (11)$$

The level of partition is finished in step 5 utilizing the acquired reachability matrix. In step 6, a resultant graph is generated based on the partition level, and transitive linkages are deleted using the transitivity rule. Finally, in step 7, substituting statements for the barriers nodes in the ISM hierarchical structure of the completed digraph.

RESULTS AND DISCUSSION

DEMATEL analysis

Based on the average response matrix and its normalization, a Total Response Matrix, TRM, Table 5. is generated, which provides a visual representation of the interrelationships between the barriers. This further helps to identify the significant barriers that have the greatest impact on the system, analyze the direct and indirect effects of the factors, and discover causal chains within the system. This helps in comprehending the Prominence and Relation of the barriers and deriving DEMATEL Weights of barriers.

The obtained DEMATEL weight of the barriers is illustrated in Table 6. This weight helps in identifying the prominence-relation diagram of the barriers.

The statistical finding using DEMATEL is illustrated in the form of a causal diagram in Fig. 2. The result il-

Table 5: Total response matrix of barriers

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	3.10	3.07	3.08	3.11	3.20	3.12	3.12	3.15	3.02	3.08
B2	3.01	3.05	3.02	3.06	3.15	3.07	3.06	3.10	2.97	3.01
B3	2.98	2.99	3.02	3.02	3.11	3.03	3.03	3.06	2.94	2.98
B4	3.04	3.06	3.06	3.12	3.19	3.10	3.10	3.13	3.00	3.05
B5	3.08	3.09	3.09	3.13	3.25	3.14	3.14	3.18	3.04	3.09
B6	2.89	2.90	2.90	2.93	3.02	2.99	2.94	2.98	2.84	2.90
B7	2.97	2.98	2.98	3.02	3.11	3.03	3.06	3.06	2.93	2.98
B8	2.89	2.90	2.90	2.93	3.02	2.94	2.94	3.01	2.85	2.90
B9	2.97	2.98	2.98	3.01	3.10	3.03	3.01	3.06	2.97	2.98
B10	2.91	2.92	2.91	2.95	3.04	2.97	2.96	3.00	2.87	2.96

Table 6: DEMATEL weight of the barriers

Barriers	Row Wise Sum of TRM	Column-Wise Sum of TRM	Prominence	Relation	Weight
	D	*R*	*D+R*	*D-R*	
B1	31.05	29.85	60.90	1.20	0.10082
B2	30.49	29.93	60.42	0.56	0.10003
B3	30.15	29.93	60.07	0.22	0.09945
B4	30.85	30.27	61.12	0.58	0.10119
B5	31.23	31.20	62.43	0.03	0.10336
B6	29.29	30.42	59.71	-1.13	0.09884
B7	30.11	30.35	60.46	-0.23	0.10009
B8	29.29	30.73	60.02	-1.44	0.09936
B9	30.08	29.42	59.49	0.66	0.09849
B10	29.48	29.93	59.41	-0.45	0.09836

lustrates that the barriers which are in the first quadrant have a characteristic of being high in prominence as well as high relation to the other challenges i.e. (B5) - For the peri-urban area, there are no comprehensive planning regulations or benchmarking, (B4) - Notable absence of effective spatial policy-making and a comprehensive approach to territorial governance, (B1) - Peri-urban area demarcation is ambiguous and (B2) - Insufficient development of skills and abilities within institutions. The significance of these barriers makes them the 'causes' that impede cohesive and strategic peri-urban development. Overcoming these barriers would affect the handling of other barriers as well. In the second quadrant, barriers (B9) - Lack of studies evaluating the implementation and adherence of plans after their execution, (B3) - Overlapping and multiple institutes leading to conflict in land intervention can be found. These barriers are comparatively low in prominence but are still highly related to other barriers in the domain. Therefore, these barriers are termed 'dependent barriers', The barriers which are low in prominence as well as relation is illustrated in the third quadrant. This means that (B10) - *Exhibit high levels of informality in land use and tenure arrangements,* (B6) - *Lack of cadastral data for spatial assessment of Land,* and (B8) - Insufficient policies, plans, methods, and evaluations to curb unauthorized exploitation of natural and agricultural resources can be termed as 'independent' challenge. In the fourth quadrant, the challenge that is illustrated is B7-Lack of Limitations on Metropolitan Overgrowth in the Periphery, which has high prominence but less relation with other barriers. These barriers are therefore termed 'effects'.

Modified DEMATEL ISM analysis

A modified DEMATEL ISM method was used to identify the hierarchical structure of barriers and determine their interrelationships. The researchers categorized the discovered barriers in the peri-urban land development structure according to their perceived relevance and interdependencies, resulting in rank variation in resonance with the expert's opinions. The authors' rationale for prioritizing obstacles is based on their opinion that addressing problems at the highest level would serve as a strategic leverage point, exerting a more significant impact on other barriers. Conversely, the final barriers are classified as dependent barriers in the structural modeling. The presence of these barriers is mostly attributed to the insufficient resolution of the foundational issues, resulting in an extended struggle. The allocation of rank variation functions to underscore the hierarchical character of these obstacles, accentuating their interconnectedness and the possible areas of leverage for more efficient intervention. By ranking and classifying, the authors offer policymakers suggestions on how to focus resources and efforts to maximize influence on the whole peri-urban land development process. The first

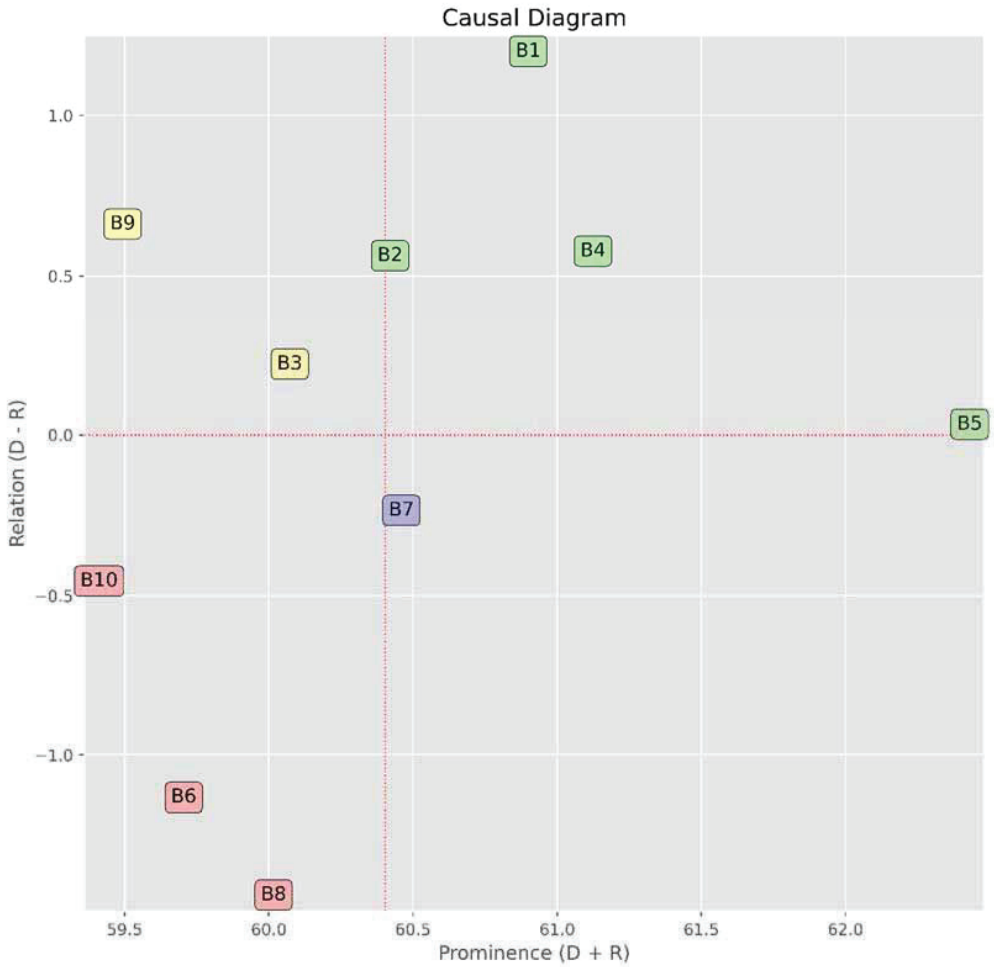

Fig. 2: Causal diagram of response from the experts

step in DEMATEL ISM analysis is to generate the initial reachability matrix (Table 7) based on the average response matrix as analyzed in DEMATEL.

The final reachability matrix (Table 8) was derived by using the rule of transitivity on the initial reachability matrix. In the given table, the Driving Power and Dependence of the barriers are shown, which will help in classifying the barriers into causes, dependent, independent, and effects. The reachability and antecedent set for each challenge are determined using the final reachability matrix. The reachability set comprises the challenge itself and other barriers that may be progressed by its help, whereas the antecedent set includes barriers itself and other barriers that may aid in its progress. The intersection of these sets is then calculated for each challenge. The top-level element in the ISM hierarchy is the one with the same reachability and intersection sets. After identifying the top-level challenge, it is split from the other barriers. The following level of components is then discovered using the same method as illustrated in Tables 9, 10, and 11.

In iteration 1, challenges B3, B6, B7, B8, and B10 are placed at level I as it does not have an impact on other barriers.

In iteration 2, barriers B4, B5, and B9, are

Table 7: Initial reachability matrix of barriers

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	0	1	0	1	1	0	0	0	1
B2	0	1	0	1	1	0	0	0	0	0
B3	0	0	1	0	0	0	0	0	0	0
B4	0	0	0	1	1	0	1	0	0	0
B5	0	0	0	1	1	0	1	1	0	1
B6	0	0	0	0	0	1	0	0	0	0
B7	0	0	0	0	0	0	1	0	0	0
B8	0	0	0	0	0	0	0	1	0	0
B9	0	0	0	0	0	0	0	1	1	0
B10	0	0	0	0	0	0	0	0	0	1

Table 8: Final reachability matrix of barriers

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Importance
B1	1	0	1	1	1	1	1	1	0	1	8
B2	0	1	0	1	1	0	1	1	0	1	6
B3	0	0	1	0	0	0	0	0	0	0	1
B4	0	0	0	1	1	0	1	1	0	1	5
B5	0	0	0	1	1	0	1	1	0	1	5
B6	0	0	0	0	0	1	0	0	0	0	1
B7	0	0	0	0	0	0	1	0	0	0	1
B8	0	0	0	0	0	0	0	1	0	0	1
B9	0	0	0	0	0	0	0	1	1	0	2
B10	0	0	0	0	0	0	0	0	0	1	1
Relation	1	1	2	4	4	2	5	6	1	5	23

Table 9: Iteration 1

S.No.	Reachability set	Antecedent set	Intersection set	Level
1.	1,3,4,5,6,7,8,10	1	1	
2.	2,4,5,7,8,10	2	2	
3.	3	1,3	3	
4.	4,5,7,8,10	2,4,5	4,5	
5.	4,5,7,8,10	1,2,4,5	4,5	I
6.	6	1,6	6	
7.	7	1,2,4,5,7	7	
8.	8	1,2,4,5,8,9	8	
9.	8,9	9	9	
10.	10	1,3,4,5,10	10	

Table 10: Iteration 2

S.No.	Reachability set	Antecedent set	Intersection set	Level
1.	1,4,5	1	1	
2.	2,4,5	2	2	
4.	4,5	1,2,4,5	4,5	II
5	4,5,	1,2,4,5	4,5	
9.	9	9	9	

Table 11: Iteration 3

S.No.	Reachability set	Antecedent set	Intersection set	Level
1.	1	1	1	III
2.	2	2	2	

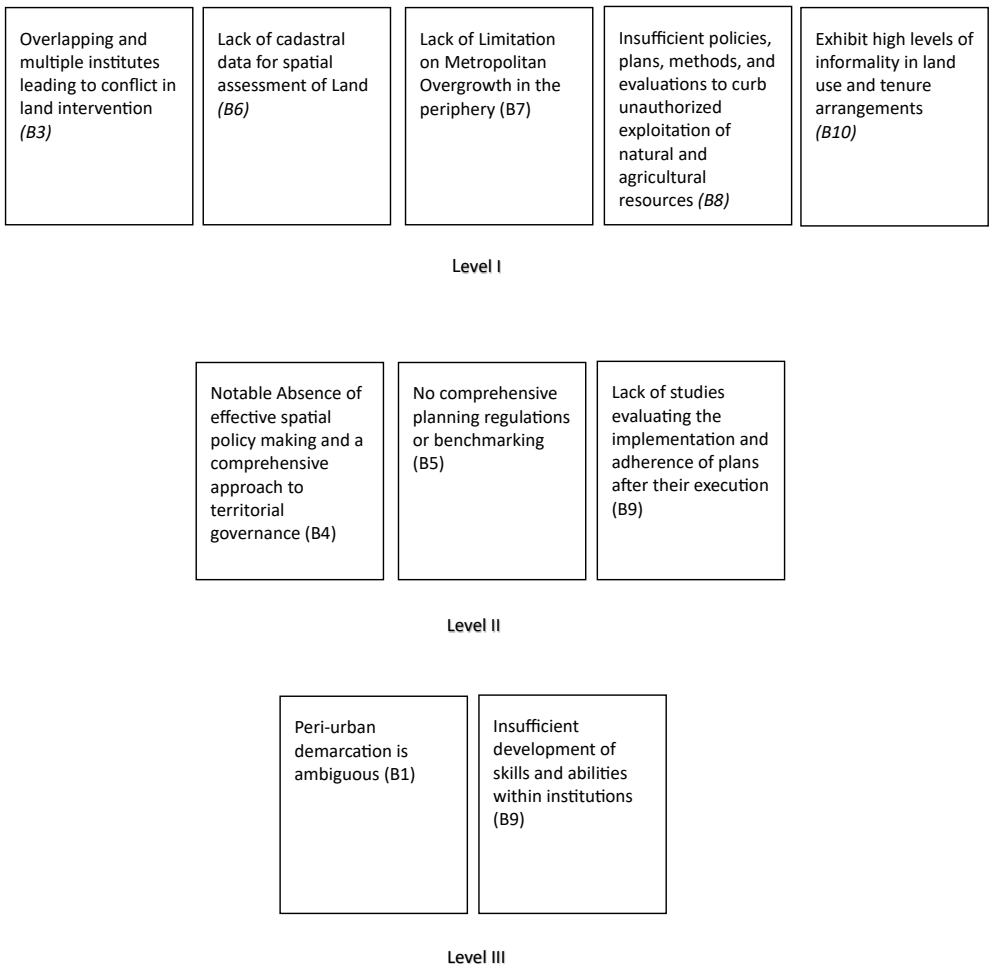

Fig. 3: ISM-based model of the challenges in peri-urban land development

eliminated and put in level 2. Furthermore, in iteration 3, the barriers B1 and B2, are kept together in level III, as it has the most impact on the rest of the barriers in the domain.

The findings suggest that the two most significant challenges are B1 and B2. It implies that if the challenge of peri-urban demarcation (B1) and capacity building of urban local bodies (B2) are dealt with, it may be able to help deal with the next level of barriers in the structure as illustrated in Fig. 3. The barriers of not having a comprehensive territorial governance approach and absence of effective spatial policy-making (B4), absence of comprehensive planning and benchmarking for peri-urban areas (B5), and Lack of studies conforming to the planning measures and the post-implementation evaluative mandates (B9) are highly dependent on challenge B1 and B2. Therefore, if these barriers are addressed, it would help the planners to get a hold of the other barriers; B4, B5, and B9. While addressing the issues in the

peri-urban land development process, policymakers should prioritize the above-mentioned barriers as they would have more impact on the overall process. Also, the last structural modeling of barriers; B3, B6, B7, B8, and B10 are more of dependent barriers. They are mostly present because the rest of the barriers are not addressed and act as an extended challenge. Overlapping and Multiplicity of the institutes (B3), Lack of cadastral data for spatial assessment (B6), Lack of control on metropolitan encroachment in the peripheral areas (B7), insufficient and ineffective policies to control unauthorized exploitation of agricultural and other resources (B8), and high informality of land (B10) are the barriers at the least level, their significance is less and their dependency on the other barriers in the structure is high.

This study sought to identify and characterize peri-urban land development challenges based on their relevance and interconnection. The causal diagram shows four sorts of constraints to peri-urban land development: determinants/causes dependent, independent, and effects. The study statistically maps peri-urban land development restrictions. This structured and visual representation reduces complex barrier links, facilitating analysis and decision-making. The study also discusses the policy implications of prioritizing peri-urban delineation and ULB capacity building to address the other issues of spatial planning policies, comprehensive planning regulations, and post-implementation evaluation studies. Planners and policymakers could also create and prioritize successful policies and resource allocation with stated challenges. Experts recommended explicit peri-urban planning and development laws to address challenges. The guideline should instruct institutes and urban local authorities on spatially executing concepts. Designating peri-urban zones at various dimensions, including communities and continuous clusters on the city's outskirts is also a prospected intervention. The policymakers-focused research addresses complex Indian city peri-urban land development issues. 122 planners and professors add credibility to the study as the practical experiences and viewpoints of these experts complete barrier research and offer authenticity. Unfortunately, time and scope constraints limit the study to North Indian towns, which may limit its applicability to other Indian cities' peri-urban problems due to regional complexities. Developers, communities, and NGOs also affect peri-urban growth dynamics and difficulties. However, their perspectives are not covered in the study. The study suggests several recommendations and inferences, including 'causes' that policy-makers and planners should prioritize. The URDPFI guidelines' delineation and regulatory framework for peri-urban areas are unclear and fail to reflect their dynamic nature. Thus, Metropolitan and District Planning Committees must actively create a phased boundary projection using GIS and decision sciences. Regional and metropolitan strategies sometimes ignore peri-urban fluctuations. To develop practical solutions, a more specialized territorial strategy is needed. This can be done by compiling ideal approaches in various contexts to aid planners in constructing local area plans. Additionally, urban development in surrounding regions necessitates immediate answers. A zonal plan that prioritizes green spaces and agriculture can achieve this. This plan prohibits land use changes and prevents surrounding construction projects from using these sites. This can be done with zonation software, using blue-green infrastructure, and ecosystem services. Capacity-building programs are needed to achieve these goals since governing body professionals must be technically proficient. The study is methodologically sound, supports global sustainability goals, addresses related challenges, and is policy-relevant. It aids Indian city officials in making crucial peri-urban land development decisions. The study can help researchers understand locals, developers, environmental groups, and NGOs. Understanding stakeholder goals helps make peri-urban development more inclusive and sustainable. Another study can explore comprehensive Indian peri-urban case studies to discover their particular difficulties and solutions. The chosen case studies would show how to tackle comparable issues elsewhere.

CONCLUSION

Periurbanization is an inevitable phenomenon occurring globally, leading to urban development and expansion in a haphazard manner. This phenomenon is especially bringing in an inequitable and non-conforming development pattern with unfair distribution of resources to the cities. It has become increasingly important to address the unchecked development and prepare measures to streamline it as prescribed in SDG 11. In this study, the authors

have attempted to comprehend the challenges that lead to this form of fragmented development and understand the relation among the challenges for its effective resolutions. 122 experts from varied Indian cities were surveyed via online Google form during April 2023 to collect their responses on the significance and interrelationship of the multifaceted challenge that persists in the literature and hinders the efficacy of peri-urban land development. The response is analyzed using the MCDM technique of DEMATEL ISM which provides a visualization of the hierarchy of the challenges. This study contributes to the advancement of knowledge on the causal relationships between barriers to peri-urban land development by elucidating the underlying causes, as well as the dependent and independent barriers, and their resultant effects. The study has identified some important variables that impede the expansion of peri-urban areas. Through a thorough review of existing literature, the study has inferred ten key challenges (B1-B10) and aims to evaluate their interconnection and relationships using the DEMATEL ISM approach. The findings indicate that out of the ten barriers identified, the most significant ones hindering peri-urban land development are: (B1) ambiguous peri-urban delineation, (B2) insufficient capacity development of local institutions, (B4) ineffective spatial policy-making and absence of territorial governance approach, and (B5) absence of comprehensive planning regulations for peri-urban areas. These barriers can also be referred to as 'causes' that impede peri-urban land development. Lack of studies evaluating the implementation and adherence of plans after their execution, (B3) - Overlapping and multiple institutes leading to conflict in the land intervention are found to be minor yet strongly related to others in the domain, thus these barriers can be called 'dependent barriers'. The study also identifies low-profile and low-relationship barriers; (B10) - Exhibit high levels of informality in land use and tenure arrangements, (B6) - Lack of cadastral data for spatial assessment of Land, and (B8) - Insufficient policies, plans, methods, and evaluations to curb unauthorized exploitation of natural and agricultural resources, as 'independent' challenge. In the fourth quadrant, B7-Lack of Limitations on Metropolitan Overgrowth in the Periphery is prominent but unrelated to other barriers. Therefore, these barriers are called 'effects'. Furthermore, the study's findings also illustrate the hierarchical organization of these problems by identifying barriers that exert the greatest influence on other barriers. The analysis identifies that the resolution of obstacles B1 and B2 may yield the most advantageous and wide-ranging impact on other barriers, highlighting importance for planners and policymakers to prioritise obstacles B1 and B2. Doing so has the potential to result in positive outcomes and significant impacts in addressing other challenges, such as enhancing the capacity of local institutions, improving spatial policy-making, strengthening territorial governance, facilitating post-implementation evaluation strategies for land interventions, and addressing issues related to the informality of land. The implicit structure of the barriers provides policymakers with valuable insights regarding the efficiency of resource allocation, the execution of targeted policies, and the prioritization of the most significant issues. Thus, it can be concluded that the implications of the findings are relevant to contemporary peri-urban planning and practice, and include a wide range of advantages in planning and policy-making: a) The findings of this study can provide valuable insights for policymakers in formulating comprehensive policies and recommendations; strategically concentrating on addressing the most pressing issue initially, through an in-depth understanding of the cause-and-effect relationships between different barriers. b) Through the process of identifying the primary challenges and their interconnectedness, stakeholders can enhance their resource allocation strategies, prioritizing the root causes that exert the most significant influence on other barriers. c) Capacity building and training initiatives can be informed by the study's findings, enabling policymakers to develop targeted programs that effectively address the highlighted challenges. This will enable institutions to more effectively address barriers to peri-urban development, enhance their capacity for planning, and ensure long-term and equitable outcomes. To advance the study's outcomes, further investigation can be conducted by researchers to explore other challenges or conduct case studies in specific instances, to enhance comprehension and offer solutions that are more tailored to the specific case. Additionally, evaluation of urban planning strategies and land development policies and schemes would enhance the concept of informed decision-making.

AUTHOR CONTRIBUTIONS

S. Sareen conceptualized, analyzed, and prepared the manuscript. M. Haque supervised, reviewed, edited, and formatted the manuscript.

ACKNOWLEDGEMENT

The authors extend their gratitude to Sohail Ahmad, University of York for his guidance in the preparation of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflict 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.

ABBREVIATIONS

B	Barriers
DEMATEL	Decision-Making Trial and Evaluation Laboratory
GIS	Geographic information system
ISM	Interpretive Structural Modeling
MCDM	Multi-Criteria Decision Making
NGO	Non-Government Organization
SDG	Sustainable Development Goals
SEZ	Special Economic Zone
ULB	Urban Local Body
URDPFU	Urban and Regional Development Plans Formulation and Implementation
α	*Cronbach's Alpha value*
C	Challenegs
σ	Sigma
x	Response by participant
k	Participant number
n	Total number of participants
Xij	Average direct relation matrix
X	Average response matrix
T	Total Relation Matrix
t	threshold level
d	matrix
D	row-wise sum of the total relation matrix
R	column-wise sum of the total relation matrix
I	Initial Reachability Matrix
FRM	Final Reachability Matrix
TRM	Total Response Matrix

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HOW TO CITE THIS ARTICLE

Sareen, S.; Haque, M., (2024). Analyzing barriers in peri-urban land development for informed policymaking. Int. J. Hum. Capital Urban Manage., 9(3): 489-508.

DOI: 10.22034/IJHCUM.2024.03.09

URL: https://www.ijhcum.net/article_712213.html

Int. J. Hum. Capital Urban Manage., 9(3): 509-520, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Investigating the impact of process parameters on waste tire pyrolysis and characterizing the resultant chars and oils

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ARTICLE INFO

Article History:
Received 29 October 2023
Revised 06 December 2023
Accepted 5 March 2024

Keywords:
Colorific value
Detailed Hydrocarbon Analysis (DHA)
Tire scrap
Thermogravimetric analysis (TGA)

ABSTRACT

BACKGROUND AND OBJECTIVES: The escalating global population, coupled with increased transportation needs and car production, has led to a surge in waste tire generation, reaching billions annually. Recognizing the environmental impact, there's a growing focus on utilizing waste tires as secondary raw materials and energy sources. Despite challenges posed by tire resilience and resistance to degradation, the current study advocates for pyrolysis as an eco-friendly method to recycle tires. It explores key process parameters (temperature and residence time) in pyrolysis, emphasizing qualitative and quantitative analyses of resulting oils compared to other products. The goal is to contribute to sustainable tire waste management and resource recovery.

METHODS: The study employed Thermogravimetric analysis for rubber's thermal characteristics, Fourier Transform Infrared Spectroscopy for pyrolysis oil analysis, Detailed Hydrocarbon Analysis using a VARIAN CP-3800 instrument, and a bomb calorimeter (Parr 1256) for measuring heat capacity in obtained oils.

FINDINGS: The yields of pyrolysis oil, char and gas were 20–32.5, 45-60, and 5-30 wt.%, respectively. The Detailed Hydrocarbon Analysis results ranged from 5-20 showed that pyrolysis oils consisted mainly of 2,3-dimethylbutene, 2-methylbutene, t-isobutyl-4-ethyl-benzene, and 1-m-4-Isopropyl-benzene. Fourier Transform Infrared Spectroscopy showed the increase of aromatic components with increasing pyrolysis temperature. The measuring of highest calorific value of pyrolysis oil was 10309 Cal/g which showed good compatibility with commercial heating oils.

CONCLUSION: Pyrolysis oils from waste tires exhibit calorific values comparable to commercial heating oils, suggesting a promising alternative fuel source with versatile compositions. The findings help to understand the feasibility and potential applications of waste tire pyrolysis in sustainable energy solutions.

DOI: 10.22034/IJHCUM.2024.03.10

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
35	3	6

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

The substantial global rise in population and concurrent growth in transportation demands, along with increased car production, have contributed to a surge in the generation of waste tires. Annually, billions of scrap tires are produced globally (Hita *et al.,* 2016; Nejatian *et al.,* 2023; Pazoki and Ghasemzadeh, 2020). It is estimated that the amount of 198,346-339,678 tons of tire waste in Iran reached the end of life during 2003-2015 (equals 2.3955-4.52 kg per capita per year) (Zarei *et al.,* 2018). This has prompted a growing interest in addressing environmental concerns (Karbassi and Pazoki, 2015) and recognizing the valuable potential of waste tires as secondary raw materials and energy resources. The focus on recycling or reusing rubber waste has intensified in recent years (Pazoki *et al.,* 2018). Effectively managing the recycling and disposal of worn-out tires presents notable hurdles owing to their durability and resistance to natural breakdown. Although the considerable calorific content of discarded tires renders them suitable for burning, the release of harmful gases during the combustion process raises environmental apprehensions, constituting a noteworthy obstacle in the current era. At present, the utilization of pyrolysis emerges as a distinctive and eco-conscious approach to repurpose and recycle scrap tires. This method entails transforming tires into valuable commodities, such as liquid fuels, offering a sustainable alternative (Kaminsky *et al.,* 2009). Numerous methods and reactors have been utilized in the pyrolysis of discarded tires, and thorough investigations have been carried out to analyze and define the products derived from the pyrolytic process (Choi *et al.,* 2014; López *et al.,* 2010; Rushdi *et al.,* 2013; Williams and Brindle, 2003). A major output of pyrolysis is oil, holding the potential for the production of valuable chemicals like toluene, xylene, benzene, and limonene (Islam *et al.,* 2008). Additionally, pyrolysis produces gas and char, both valuable materials. The char primarily comprises carbon black, and the gases consist of C_1 to C_4 organic compounds (Sahouli *et al.,* 1996; Tajfar *et al.,* 2023). Certain research endeavors focused on scrutinizing the influence of residence time, oxygen concentration, and feedstock flow rate on the production and features of carbon black obtained from the pyrolysis oil of used tires. This examination maintained a consistent temperature throughout the study (Heidary, 2017; Wen *et al.,* 2023). Toth *et al.* (2018) supported and validated these conclusions by illustrating a surge in carbon black yield from biomass pyrolysis oil with an elevation in temperature from 900 to 1300 °C. Nevertheless, the yield experienced a decline, reaching as low as 7% at a temperature of 1700 °C (Toth *et al.,* 2018). The results revealed a decrease in output as residence time and oxygen concentration increased. Notably, the BET surface area demonstrated an augmentation at elevated oxygen concentrations but saw a decline with prolonged residence times. Distinct variations in both yield and primary particle size of carbon black were observable across diverse samples of pyrolysis oil derived from spent tires. In a separate study, Ono *et al.* (2012) utilized benzene as a feedstock and observed a reduction in the primary particle size of carbon black from 40 to 31 nm as the temperature increased from 1200 to 1400 °C (Ono *et al.,* 2012). More recently, Okoye *et al.* (2022, 2021b) explored the influence of process variables (reaction temperature, residence time, and oxygen concentration) on the yield and quality of carbon black produced from spent tire pyrolysis oil and heavy residue fraction (Okoye *et al.,* 2022, 2021). Their findings indicated a significant improvement in carbon black properties (BET surface area, carbon content, and volatile matter) with increasing residence time, oxygen concentration, or reaction temperature. However, this enhancement came at the cost of carbon black yield, suggesting a trade-off in selecting process variables (Wen *et al.,* 2023; Pazoki *et al.,* 2020). Presently, numerous studies have investigated the impact of process parameters on the co-pyrolysis of coal and waste tires. These studies revealed that factors such as temperature and blending ratio exert varying degrees of influence on the co-pyrolysis process (Abdoli and Ghasemzadeh, 2024; Ghasemzadeh *et al.,* 2022a). In another study, the inclusion of 67 wt% of tires into lignite was found to enhance tar yield consistently across various pyrolysis temperatures. This indicates favorable synergies for tar production at all mixing ratios (Acar *et al.,* 2011). In a separate investigation, it was reported that there existed a positive synergy for tar production with coal/tire mixing ratios of 9/1 and 8/2 at temperatures ranging from 400 to 800 °C during co-pyrolysis (Brat *et al.,* 2022). Moreover, the rate of heating emerged as a pivotal factor influencing the synergy between coal and tires. Onay and Koca (2015)

found that higher heating rates promoted interactions between coal and waste tires for tar production, leading to improved yield and quality (Onay and Koca, 2015). Conventional heating approaches, like electrical resistance heating, encounter difficulties in attaining high heating rates. Conversely, the infrared fast-heating fixed-bed reactor presents a solution, leveraging its benefits of a rapid heating rate of up to 30 °C/s and a relatively substantial sample loading (gram). This allows for thoroughly exploring and comprehending interactions during co-pyrolysis (Onay and Koca, 2015; Tokmurzin *et al.,* 2019). This study deals with the process parameters including temperature and residence time in pyrolysis of waste tire products like chars and oils. Also, the aim was both qualitative and quantitative analyses of the produced oils in comparison to other derived products. The current study was carried out at the University of Tehran in 2022.

MATERIALS AND METHODS

Feedstock preparation

In general, the waste tires consisted of a combination of at least three distinct rubber types, namely Natural Rubber (NR), Styrene Butadiene Rubber (SBR), and Polybutadiene Rubber (PR). The powder derived from waste tires, devoid of any steel or fiber components, was acquired from Yazd Tire Company in Iran. The waste tire powder, with particle sizes ranging from 0.2 to 1 mm, served as the direct feedstock for the pyrolysis experiments. Also, the sampling of the input raw materials of the pyrolysis process was done at one time so that the change error in the input feedstock could be greatly reduced. Acetone and 2-propanol were used for the separation of oils and was purchased from Merck, Germany.

Pyrolysis process

The decomposition of waste tire took place within a fixed bed reactor, comprising a 316 SS tube with a diameter of 33mm, length of 25cm, and a volume of 105ml. Before each experiment, 20 g of rubber powder was introduced into the reactor and subjected to heating using an electric laboratory chamber furnace (Oxiton model 1200 made in Iran). The specific time and temperature parameters were chosen based on the experimental design for each trial. To mitigate the influence of residual oxygen on pyrolysis products, nitrogen gas was purged into the reactor. Upon reaching the designated reaction temperatures (400-600 °C), the sealed reactor was positioned inside the furnace for a predetermined duration. Subsequently, the reactor was removed from the electric furnace and allowed to cool gradually to room temperature, followed by further cooling in a refrigerator for 2 hours. To assess the impact of temperature on pyrolysis products, the reactor was weighed, and the generated gas was extracted upon opening the reactor. The difference in weight was reported as gas yields. The residual pyrolysis products were immersed in a solution of 2-propanol and acetone solvent at room temperature, and the mixture was stirred for 1 hour. Afterward, the solution was meticulously rinsed and filtered, and the remaining solid underwent overnight drying in an oven at 80°C. This residue constituted the char yield, predominantly composed of carbon black. The solvents utilized in the filtration process were separated under reduced pressure using a vacuum evaporator (Hahan Wapor model HS-2005s from Hahanshin company, South Korea). Following distillation, a nearly light phase was obtained from each liquid. These collected phases were identified as pyrolysis oil and stored for subsequent characterization. Experiments were performed three times each, and the mean of each group was presented. A schematic representation of the pyrolysis process is illustrated in Fig. 1.

Analysis and characterization

Thermogravimetric Analysis (TGA) was conducted using a thermogravimetric analyzer (TGA Mettler-Toledo/DSC/TGA1 Instruments, Switzerland) to explore the thermal characteristics of the feed material. Approximately 10–15 mg of rubber samples were employed for TGA experiments. All experiments were executed within the temperature range of 30 to 700 °C, employing a heating rate of 10 °C/min, and conducted under a nitrogen gas purge. Fourier transform infrared spectroscopy (FTIR) was employed to analyze all pyrolysis oils (model EQUINOX55, Bruker). The FTIR analysis involved 64 scans at a resolution of 4/cm in the 400 to 4000/cm range to obtain the spectra of pyrolysis oils. Detailed Hydrocarbon Analysis (DHA) was performed using a VARIAN CP-3800 instrument equipped with a Flame Ionization Detector (FID). Separations were carried out using a fumed silica capillary column (CP-SIL PONA CB) with a length of 100 m and an internal diameter

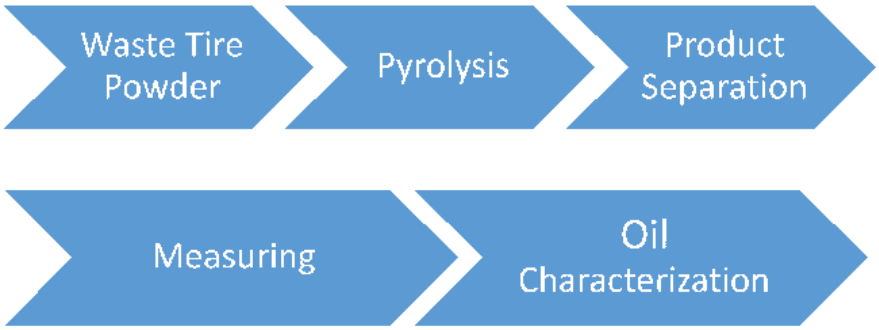

Fig.1: Schematic diagram of the pyrolysis process

of 0.25 mm. The temperature was programmed from 50 to 295 °C at a rate of 4 °C/min, with helium serving as the carrier gas. For measuring the heat capacity of obtained oils, a bomb calorimeter (Parr instrument, model 1256) was employed. The bomb calorimeter, a type of constant-volume calorimeter, was utilized to determine the heat of combustion for various types of burning samples (Abdoli and Ghasemzadeh, 2024). Each experiment involved the use of approximately 1-1.5 g of samples. The values of the results presented in each section are the average of three times of analysis.

RESULTS AND DISCUSSION

TGA experiments

Fig. 2 displays the TGA and Differential Thermogravimetric (DTG) curves for the scrap tire powder. The TGA curves indicate that thermal degradation occurred across a broad range from 200 to 500 °C, while the DTG curves distinctly reveal three decomposition regions. The initial weight loss at 200-300 °C is attributed to the degradation or volatilization of additives such as stearic acid and aromatic-naphthenic oils employed in the tire manufacturing process. The subsequent weight loss (300-380 °C) primarily results from the degradation of NR, and the third weight loss (380-500 °C) is associated with the decomposition of SBR and BR. NR and SBR constitute the main components of tires, while BR is commonly used as a liner for certain types of tires. These findings align with a prior study that utilized DTG peak temperatures of 378 °C, 458 °C, and 468 °C for NR, SBR, and BR, respectively (Moustafa *et al.,* 2016). The insights gained from this TGA study provide a foundation for designing our pyrolysis experiment. According to the TGA analysis, an optimal pyrolysis temperature range of 400-600 °C is recommended to achieve complete decomposition of waste tires.

Effect of temperature

Table 1 outlines the impact of pyrolysis temperatures (400, 450, 500, 550, and 600 °C) on the product yields. The gas yield was determined by the disparity between the quantity of feed material and the combined amount of oil and pyrolysis char. Pyrolysis oil yields ranged from 20% to 32.5% by weight of the tire waste. Char yield calculations were performed after washing and drying the pyrolysis char in an oven overnight.

Table 1 illustrates that the yields of pyrolysis products exhibit a strong dependency on the chosen pyrolysis temperatures. Optimal pyrolysis conditions seem to be around 500 °C, as at this temperature range, the yields are most favorable. Notably, increasing the pyrolysis temperature beyond this point primarily promotes the degradation of oil, converting it into gas products, mainly due to secondary cracking reactions. The solid residue from pyrolysis comprises reinforcing carbon black used in tire production and other inorganic compounds incorporated during the manufacturing process (Czajczyńska *et al.,* 2017; Ghasemzadeh *et al.,* 2022b, 2022c). Char yield fluctuates within the range of about 45 to 60 wt.%, while the gas obtained from pyrolysis can vary from 5-30 wt.% of the products, depending on the pyrolysis temperature. Interestingly, as the pyrolysis temperature increases, the char yield remains relatively constant, hovering around 45 wt.%. The correlation between product yields and temperature is visually represented in Fig. 3.

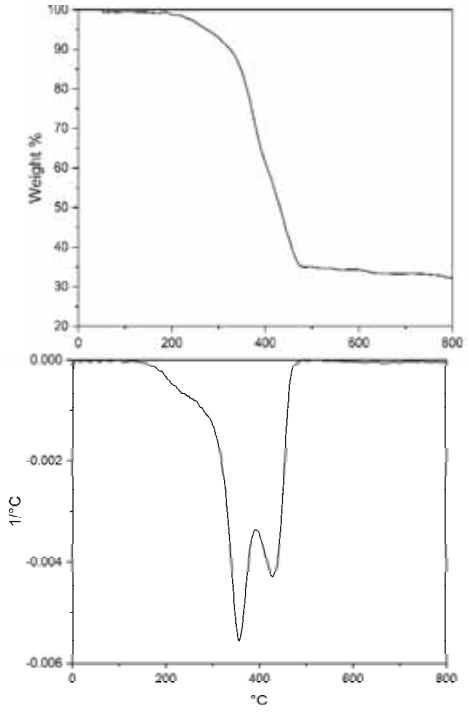

Fig. 2: Thermogravimetric analysis of the scrap tire powder

Table 1: Effect of temperature on the yields of pyrolysis products

Pyrolysis temperature (°C)	Char yield (%)	Oil yield (%)	Gas yield (%)
400	60	32.5	5
450	55	30	10
500	50	27.5	17.5
550	45	22.5	25
600	45	20	30

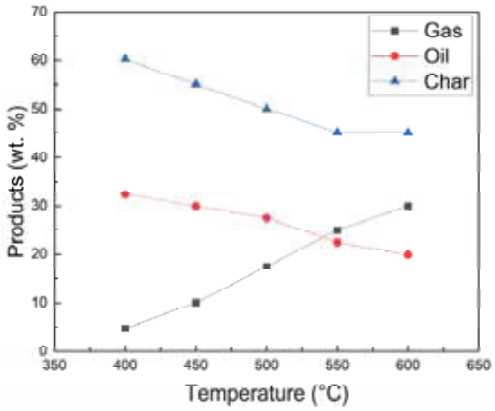

Fig. 3: Correlation between product yields and temperature

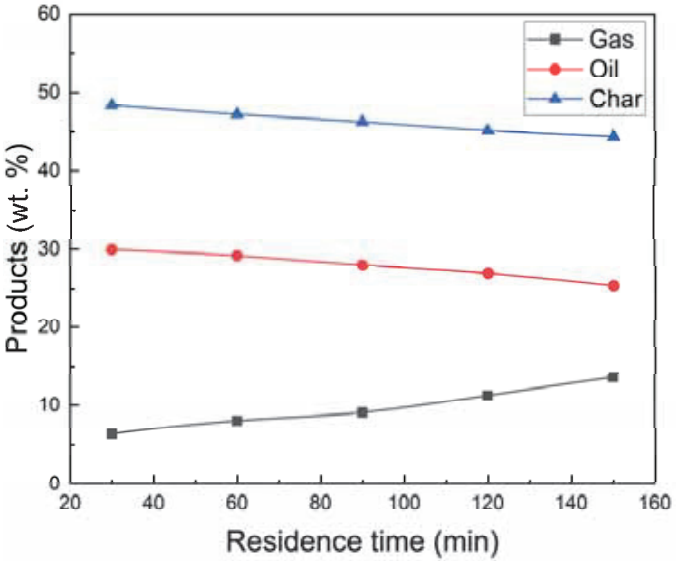

Fig.4: Effect of residence time on yields of pyrolysis products

Effect of residence time

Fig.4 shows the effect of residence time on yields of pyrolysis products at 500 °C. Different residence times such as 30, 60, 90, 120, and 150 min were examined for the pyrolysis procedure at 500 °C. As the figure shows, only slight changes are obvious in trends of yielding products. This is more obvious in the case of gases, which are increasing with increasing residence time. So in conclusion, a longer residence time has a weak influence on the yields of pyrolysis products but the direction was the same as the pyrolysis temperature for the gas product.

FTIR analysis

FTIR was employed to characterize pyrolysis oils obtained through the degradation of tire wastes at four distinct temperatures ranging from 400 to 550 °C. The analysis was conducted at room temperature using Potassium Bromide (KBr) discs and recorded over a wavenumber range of 4000–400 cm^{-1} (Fig. 5a). The IR spectra exhibit several characteristic peaks, including broadband indicative of the OH group at 3400/cm (Samimi, 2024). Additionally, absorption peaks at 3045 and 3014/cm were assigned to the C=C stretching vibrations. A narrow and moderately intense peak at approximately 1600/cm corresponds to characteristic vibrations of the aromatic nucleus (C=C), such as the benzene ring. An intense peak at 1200/cm is typical of C-O bonds. Bands observed in the range of 1000–1150/cm were attributed to the C–O–C stretching vibrations, while the stretching and bending vibrations at 2796–2950/cm and 1310–1465/cm were assigned to alkyl groups, such as CH_2 and CH_3, present in the obtained chemicals. The sample spectra of pyrolysis oil at 500 °C, along with comparisons at four different temperatures, are provided in Fig. 5b.

Although the obtained results show more or less similar absorption there are some differences between FTIR absorption of the produced oils in different pyrolysis temperatures. The evidence of FTIR spectroscopy wavenumber around 1600 and 3000/cm shows by increasing the pyrolysis temperature from 400 to 550 °C the amount of aromatic structure increases. This observation is presented in Fig. 6. This is quite obvious from sharper absorption peaks around 1600/cm and above 3000/cm which belong to aromatic structures. These bands were very small at lower temperatures and increased with increasing pyrolysis temperature, indicating that higher concentrations of aromatics were presented in higher pyrolysis temperatures. Similar results have been reported by other studies (López *et al.,* 2013; Maleki Delarestaghi *et al.,* 2018;

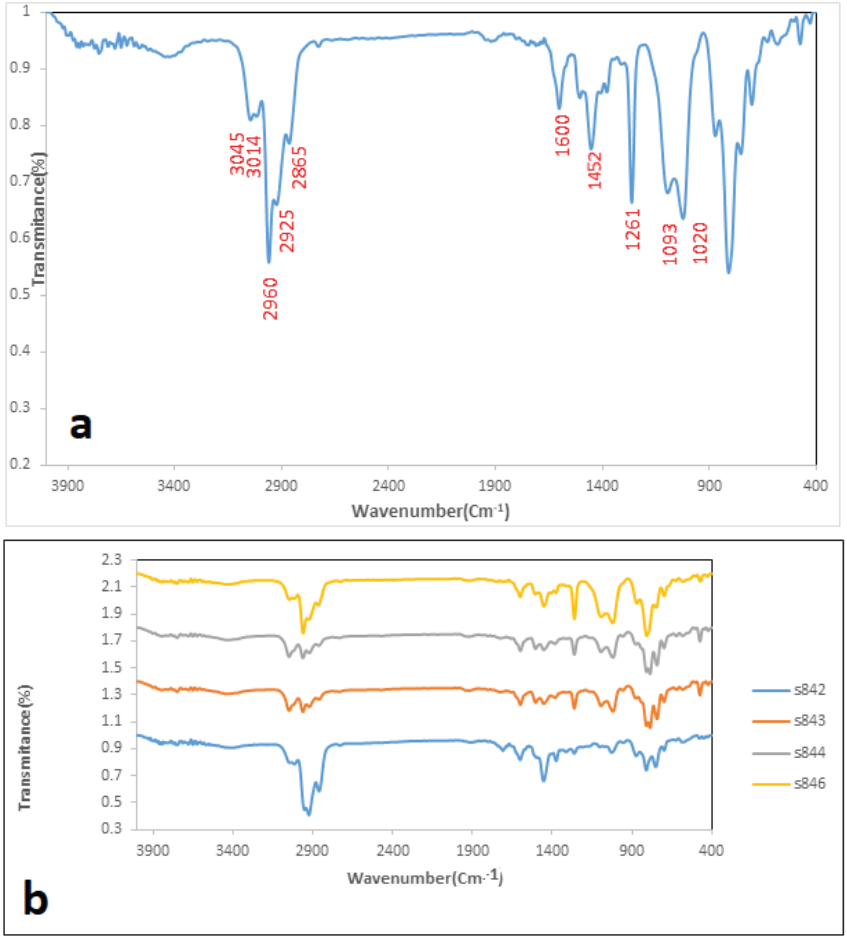

Fig. 5: FTIR spectra of pyrolysis oil a) as a sample at 500°C, b) comparing at 4 different temperatures

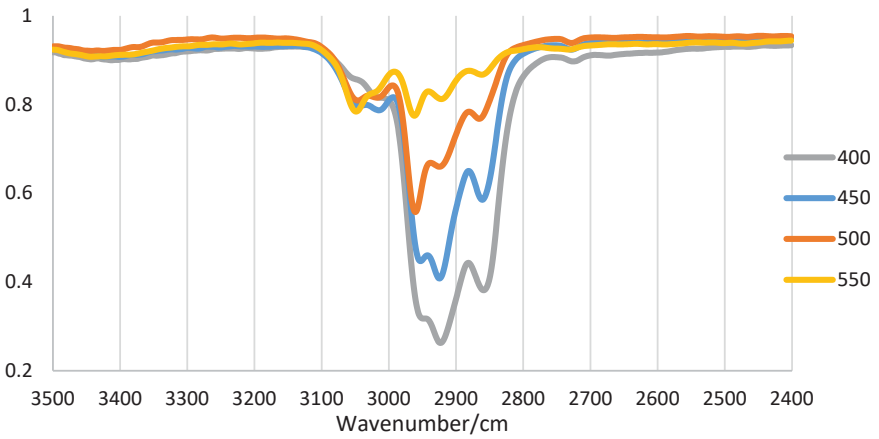

Fig. 6: Comparison between FTIR spectra of the oils produced in different pyrolysis temperatures.

Table 2: Detailed Hydrocarbon Analysis of pyrolysis oils

Sample number	Ret. Time (min)	Peak name (compound)	Pyrolysis temperature (°C)
1	8.398	1-Pentene	500
2	8.637	NC5	550
3	9.064	Cis-2-Pentene	400
4	9.215	2-Methylbutene	500
5	9.305	2,3-DMC4	400-550
6	81.979	1-m-4-Isop-benzene	400-550
7	100.115	t-IB4Ebenzene	550

Table 3: Calorific value results of waste tire pyrolysis oils

Sample number	Pyrolysis temperature (°C)	Energy (Cal/g)
1	400	10309
2	450	9800
3	500	9667
4	550	8973

Ramirez-Canon *et al.,* 2018). Aromatic formation reaction at higher temperatures is mainly due to Diels-Alder and recombination reactions between aliphatic and aromatic free radicals. It is noteworthy to mention that the chemical compositions of the pyrolysis oils are intricate due to the utilization of various types and mixtures of scrap tires in the pyrolysis process. The diverse nature of the input materials contributes to the complexity of the resulting chemical compositions in the pyrolysis oils.

Detailed Hydrocarbon analysis

DHA was performed on pyrolysis oils obtained within the temperature range of 400-550°C, and the outcomes are presented in Table 2. In summary, it can be noted that the composition of pyrolysis oils is highly intricate due to the variations in scrap tires and pyrolysis temperatures. The results indicate a diverse mixture of organic compounds ranging from 5 to 20 carbons, with a predominant presence of aromatics. Some of the identified chemicals include 1-pentene, 2-methylbutene, 2,3-dimethylbutane (DMC4), 1-m-4-Isop-benzene, and t-IB4Ebenzene. The complexity of the obtained chemicals underscores the influence of both the tire composition and the pyrolysis conditions on the resulting hydrocarbon composition. It is quite obvious that by increasing the degradation temperature, the amount of aromatic structures increases. This may be because of free radical recombination reactions and cyclization of aliphatic chains. Similar results have been obtained by another study and are also confirmed by our FTIR spectroscopic study (Dıez *et al.,* 2004).

Calorific value

Bomb calorimetry was employed to measure the calorific value (heat of combustion) of pyrolysis oils according to the ASTM D4809 standard method. In general, pyrolysis oils obtained from recycled tires exhibited a high calorific value comparable to that of commercial heating oils. This similarity renders them an attractive alternative and valuable fuel source. The results obtained through bomb calorimetry or energy content per gram of oil (Cal/g) at different pyrolysis temperatures are presented in Table 3, providing insights into the heat release capabilities of the pyrolysis oils. Within the temperature range of 400 to 550 °C, the energy content of the produced oil has decreased from 10,309 to 8,973, indicating a 13% reduction. This implies that when the temperature of the pyrolysis process increased, the energy content of the produced oil decreased. These findings align with other studies in the field (Heidary, 2017; Dıez *et al.,* 2004).

The utilization of waste tire pyrolysis emerges as a valuable avenue for extracting oil from discarded materials, offering a solution with multifaceted economic benefits. The resulting oil showcases a spectrum of properties contingent upon diverse process parameters, including residence time and temperature. While some studies have

explored the economic feasibility of pyrolysis processes, in Iran's context, characterized by relatively low energy prices, economic viability pivots on addressing environmental concerns or capitalizing on government incentives directed toward bolstering sustainable energy production. Various factors, spanning plant longevity, feedstock composition, technological variables, and biomass pricing, collectively shape the economic feasibility of oil extraction through pyrolysis. Key to evaluating market competitiveness against other biofuels is the production cost linked with char and oil. This cost is susceptible to influence from a range of factors encompassing pretreatment methods, upgrading techniques, and recycling practices. Approaches such as biomass torrefaction as a pretreatment strategy and the adoption of cost-efficient catalysts for oil refinement show promise in rendering biomass pyrolysis for oil extraction financially viable. Additionally, implementing a self-sustaining pyrolysis process holds the potential for substantial cost reductions, positioning it as the most economically advantageous option on a commercial scale. The study focused on examining key parameters such as temperature and residence time in pyrolysis processes, aiming to evaluate resulting oils qualitatively and quantitatively in comparison to alternative products. However, potential sources of error exist within the analysis, and the underlying assumptions require improvement to enhance reliability. These sources of error include inaccuracies in measurement precision, risks of sample contamination, variability in feedstock characteristics, and assumptions made during analysis. To address these issues, researchers could refine measurement techniques, implement robust quality control measures, standardize feedstock characteristics, and validate assumptions through sensitivity analyses or control experiments. By mitigating these potential sources of error and enhancing underlying assumptions, the study can achieve greater reliability and validity in its findings, ultimately strengthening the significance of its conclusions.

CONCLUSION

The rising global population and increased transportation needs have led to a significant annual production of billions of waste tires. To address the environmental impact, there is a growing focus on repurposing these tires as secondary raw materials and energy sources. Despite challenges posed by tire resilience, a recent study advocates for using pyrolysis as an eco-friendly method for recycling tires. The research explores key parameters like temperature and residence time in pyrolysis, emphasizing both qualitative and quantitative analyses of resulting oils compared to other products. The goal is to contribute to sustainable tire waste management and resource recovery. This study investigated the pyrolysis of waste tire powder at various temperatures and yielded pyrolysis oils, with a notable range in yields (20 to 32.5 wt.%), dependent on the final pyrolysis temperature. This process also generated pyrolysis char (45 to 60 wt.%) and gas (5 to 30 wt.%). Detailed Hydrocarbon Analysis identified key compounds in the pyrolysis oils, including 1-pentene, 2-methylene, 2,3-dimethylbutane, 1-m-4-Isop-benzene, and t-IB-4Ebenzene. Fourier Transform Infrared Spectroscopy revealed a temperature-dependent shift, with an increase in aromatic structures and a decrease in aliphatic components. Moreover, the calorific value comparison demonstrated that pyrolysis oils from waste tires are on par with commercial heating oils, indicating their potential as a valuable alternative fuel source. This comprehensive analysis underscores the versatility of waste tire pyrolysis in producing oils with diverse compositions and energy characteristics. The findings contribute to understanding the feasibility and potential applications of waste tire pyrolysis in sustainable energy solutions.

AUTHOR CONTRIBUTIONS

A. Pazoki performed conceptualization, investigation, and interpreted the data. R. Ghasemzadeh wrote the draft manuscript and reviewed the literature. M. Barikani performed experiments and investigation in the literature review and manuscript preparation. M. Pazoki analyzed and interpreted the data.

ACKNOWLEDGEMENT

The authors would like to thank Dr. E Sotoudeh for his assistance in providing a waste tire powder sample from the Yazd rubber industries complex, in Iran, and our sincere thanks go to Dr. M Barikani for his immense knowledge and insightful comments on

this study.

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)

BR	Polybutadiene Rubber
DHA	Detailed Hydrocarbon Analysis
DTG	Differential Thermogravimetric
FTIR	Fourier Transform Infrared Spectroscopy
FID	Flame Ionization Detector
KBr	Potassium Bromide
NR	Natural Rubber
SBR	Styrene Butadiene Rubber
TGA	Thermogravimetric Analysis

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HOW TO CITE THIS ARTICLE

Pazoki, A.; Ghasemzadeh, R.; Barikani, M.; Pazoki, M., (2024). Investigating the impact of process parameters on waste tire pyrolysis and characterizing the resultant chars and oils. Int. J. Hum. Capital Urban Manage., 9(3): 509-520.

DOI: 10.22034/IJHCUM.2024.03.10

URL: https://www.ijhcum.net/article_711669.html

Int. J. Hum. Capital Urban Manage., 9(3): 521-536, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Dynamics of urban growth in mid-sized cities using census data

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ARTICLE INFO

Article History:
Received 04 October 2023
Revised 11 January 2024
Accepted 28 February 2024

Keywords:
Mid-Sized cities
Urban growth
Urban sprawl
Urban expansion

ABSTRACT

BACKGROUND AND OBJECTIVES: Currently, 56% of the global population, resides in cities, and this urbanization trend is predicted to result in more than doubling of the urban population by 2050. Similarly, mid-sized Indian cities have exhibited rapid urban growth in recent decades. However, a holistic study focusing on the temporal dynamics of urban growth in all the mid-sized Indian cities is lacking. Therefore, this study aims to investigate the urban growth pattern across eighty-eight mid-sized Indian cities with the help of Census data from 1971-2011.

METHODS: This research, utilizing a quantitative approach, investigates the relationship between economic growth and urban expansion in selected cities. The cities are categorized based on the Gross State Domestic Product of respective states, and the study evaluates changes in municipal areas and demographic growth patterns through the decadal urban expansion rate and decadal population growth rate. The urban growth character is further analyzed by dividing the population growth rate by the decadal urban expansion rate, with a value less than 1 indicating inefficient land utilization. This comprehensive methodology aims to provide insights into the dynamics of urban growth and its correlation with economic development.

FINDINGS: The results revealed that inefficient land utilization for urban growth during 1971-2011 had occurred in thirteen cities from the states with higher Gross State Domestic Product and three cities among the states with lower Gross State Domestic Product. Overall, the mid-sized Indian cities, such as Ajmer (0.65), Solapur (0.67), Asansol (0.79), Mangalore (0.83), Jhansi (0.84), Nellore (0.85), Belgaum (0.86), Thrissur (0.86), and Bareilly (0.89) exhibited the lowest PU values during 1971-2011. The major drivers for urban growth in mid-sized Indian cities are government policies and schemes, industrial growth, rise in Gross State Domestic Product, climatic conditions and terrains, social profile, transportation, and infrastructure.

CONCLUSION: Overall, there has been inefficient land utilization in several cities, particularly those from states with varying levels of Gross State Domestic Product. Noteworthy cities like Ajmer, Solapur, and Belgaum consistently demonstrated efficient land utilization, reflected in their lower Population-to-Urban Expansion values. The study emphasizes the intricate influences shaping urban growth, encompassing government policies, industrial development, economic factors, climate, social dynamics, and infrastructure. Future research endeavors could further delve into the specific impact of these factors on urban expansion, employing longitudinal analyses, and exploring the socio-economic ramifications of efficient or inefficient land utilization, contributing to more informed urban planning and policy formulation.

DOI: 10.22034/IJHCUM.2024.03.11

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
67	3	5

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

Today more than half of the global population resides in urban areas compared to 1950, when only 30% of the total population was urbanized (United Nations, 2018). Asia is home to 53% of the global urban population despite a low rate of urbanization (United Nations, 2019). Urbanization and urban growth are often used synonymously although there exists a significant difference between the two processes. Urbanization refers to a phenomenon wherein rural areas are transformed into urban areas primarily due to population immigration and changes in economic activities, while urban growth is a spatial process that promotes the expansion of cities (Bhatta, 2009; Bhatta, 2010). Urban areas are the engines of growth, i.e., they are the drivers that trigger economic, social, and cultural growth by creating wealth and generating employment, which ultimately leads to the development of humans (Akanbang *et al.,* 2021). Hence, it is assumed that urban living has better access to education, jobs, health facilities, and other social services, along with prospects for cultural and political participation (Chettry, 2023). However, rapid and haphazard urbanization in the last few decades has affected humans and, most importantly, the natural environment (Subadyo *et al.,* 2019; Chandrashekar and Aithal, 2021; Sethi *et al.,* 2021; Amare *et al.,* 2023). The cities and adjoining areas during this process of rapid urbanization were subjected to rapid growth leading to the development of peri-urban growth (World Bank, 2013; Hennig *et al.,* 2015; Hsu *et al.,* 2016). The major characteristics of urban growth include but are not limited to low-density development (Jiang *et al.,* 2007; Yue *et al.,* 2016); dispersed growth (Salvati and Carlucci, 2015; Ozturk, 2017; Chandrashekar and Aithal, 2021), vehicle dependent (Jain and Pallagst, 2015; Nielsen, 2017), growth along major roads (Tian *et al.,* 2017), poor environment (Bhattacharya, 2019; Dewa *et al.,* 2023), and poor quality of life (Bhat *et al.,* 2017; Oladehinde *et al.,* 2021). Currently, in India, there are 7933 cities and towns of different population sizes and cumulatively it accounts for 377.16 million (Jain *et al.,* 2019). The total urban population in India is approximately 11% of the global urban population and is expected to reach 13% by 2030. It is estimated that half of the population in India will live in cities by 2050, leading to a significant transition in urban areas (United Nations, 2015). In 2015, urban India contributed 63% of the Indian Gross Domestic Product (GDP), and a further increase is expected up to 75% by 2030 (Kantakumar *et al.,* 2016). Due to such tremendous urban growth in India over the years, there have been haphazard land cover changes (Kumar and Tripathi, 2014; Jain *et al*., 2017). Moreover, the urban growth in large Indian cities (population >5 million) occurred primarily through expansion towards the periphery (Sahana *et al.,* 2018). The large cities have already exceeded the threshold level of carrying capacities, and as a result, there has been a rise in pollution levels, traffic congestion, and a lack of infrastructure, facilities, and services (Ramachandra and Aithal, 2013). Furthermore, in recent decades mid-sized Indian cities (population 0.5-5 million) have also exhibited rapid urban expansion towards the periphery (Chettry, 2023a). However, a comprehensive study of all the eighty-eight mid-sized Indian cities to understand the urban growth pattern is missing from the literature. Moreover, the 11th Sustainable Development Goal (SDG) of the 2030 Agenda for Sustainable Development adopted by the United Nations Member States in 2015 emphasizes promoting sustainable cities and communities (United Nations, 2016). Therefore, it is essential to investigate the spatiotemporal urban growth pattern of cities to avoid unsustainable urbanization (Chettry, 2022). However, unlike China (Jiyuan *et al*., 2012), the USA Europe (Kasanko *et al.,* 2006), and other developed nations, there is a lack of an urban built-up database for Indian cities to analyze the urban growth pattern holistically. Numerous indices based on the urban land information are used to measure the growth of urban areas which includes but are not limited to Urban Expansion Rate (UER) calculated by Kantakumar *et al.* (2016) for Pune, India; Annual Expansion Rate (AER) by Zhao *et al.* (2015) for 32 major Chinese cities; Annual Growth Rate (AGR) by Espindola *et al.* (2017) for Teresina, Brazil. A comparative analysis of urban growth patterns in three metropolises of China and the USA using temporal Impervious Surface Area (ISA) datasets was done by calculating overall ISA change, annual expansion area, and annual expansion rate (Kuang *et al.,* 2014). Chen *et al.* (2014) utilized the Average Annual Population Growth Rate (AAPGR), Average Annual Urban Expansion Rate (UE), and Population Growth to Urban Expansion Ratio (PGUR) to study urban growth in Shenzhen and Dongguan during 1990-2008. PGUR is synonymous with the Land

Consumption Rate (LCR) and was used as an index to assess the dynamics of urban expansion in Bahir Dar, Ethiopia (Haregeweyn *et al.*, 2012). A similar index was used to analyze the urban growth of the Greater Accra Metropolitan Area, Ghana (Akubia and Bruns, 2019). Overall, it is a measure to understand urban growth patterns wherein the results may exhibit urban compactness or urban expansion. The Census of India collects data every ten years in India regarding the municipal expanse, demography, and socio-economic status of Indian cities and villages. Various researchers globally (Schneider and Woodcock, 2008; Garcia-López and Muñiz, 2013; Kukkonen *et al.*, 2017) as well as in India (Fazal, 2000; Das *et al.*, 2016; Sahana *et al.*, 2018) have used Census data in urban growth studies. However, most of these studies utilize the Census data only to explore the demographic characteristics of an area. Therefore, municipal area expansion data gathered from the Census of India can be used due to the lack of an urban built-up dataset for all the eighty-eight mid-sized Indian cities. A similar approach was attempted to measure the urban sprawl of Western Cape Province, South Africa due to a lack of physical urban expanse data (Horn and Eeden, 2018). Hence, in this context this research aims to investigate urban growth pattern among eighty-eight mid-sized Indian cities. It utilizes the census data for identifying mid-sized Indian cities that exhibited inefficient utilization of land resources to accommodate the rising population. The municipal expansion rate and population growth rate are quantified to investigate the urban growth pattern. The selected mid-sized Indian cities were classified into two categories based on Gross State Domestic Product (GSDP) for detailed analysis. The purpose of this study is to provide valuable insights for government agencies and city planners to address the pressing need for informed urban planning due to rapid urbanization and population growth. The findings aim to assist in formulating strategies for planned urban development. The current study has been carried out on eighty-eight mid-sized cities in India in 2023.

MATERIALS AND METHODS

Study area and datasets

India is a country in South Asia with a total area of 3.28 million km^2, the seventh-largest country by area, and the second-most populous country (1.2 billion population) as per the Census of India 2011 in the whole world (Census of India, 2011). The total urban population of the country is more than 377 million constituting 31.16% of the total population. The country has various geographic regions like Northern Mountain, Thar desert, Peninsular Plateau, Coastal Plains, and Indo-Gangetic plains. After the major economic reforms in 1991, India today is one of the fastest-growing economies of the world, fostering its cities towards growth (Chadchan and Shankar, 2012; Floater *et al.*, 2014). There are eight large cities with a population of more than 5 million (also known as Tier-I cities) and eighty-eight mid-sized cities with a population between 0.5 to 5 million (also known as Tier-II cities) in India as per the data obtained from the Ministry of Finance, Govt. of India (Fig. 1). The demographic and municipal expansion data were gathered from the Census of India detailed publication. The Census data is the official and most reliable data source to refer the demography and urban expansion data. The last Census was done is 2011 and hence the data in this study is based on Census 2011. The GSDP at Current Prices 2011-12 of all Indian states was obtained from the Central Statistical Organization, Govt. of India, New Delhi (Central Statistical Organisation, 2018). Microsoft Excel and ArcGIS 10.3 were used to analyse data and prepare maps in this study.

Methodology

The research methodology, illustrated in Fig. 2, commenced with the compilation of a list comprising eighty-eight mid-sized Indian cities obtained from the Ministry of Finance, Government of India. These cities were spatially mapped using ArcGIS 10.3. For a detailed analysis that aligns with the diverse urban growth processes within the selected cities, the GSDP of their respective states was chosen as a classification criterion. This choice was informed by the positive correlation between a city/state's economy and urban growth, as established in previous studies (UN-Habitat, 2012). The mid-sized cities were subsequently categorized into two groups based on the 75th percentile of the respective state GSDP in current prices for the base year 2011-2012 (adjusted to 2019-2020). This classification facilitated a more meaningful and contextually relevant examination of urban growth patterns within the selected cities. The list of cities is shown in Table 1 (Reserve Bank of India, 2023).

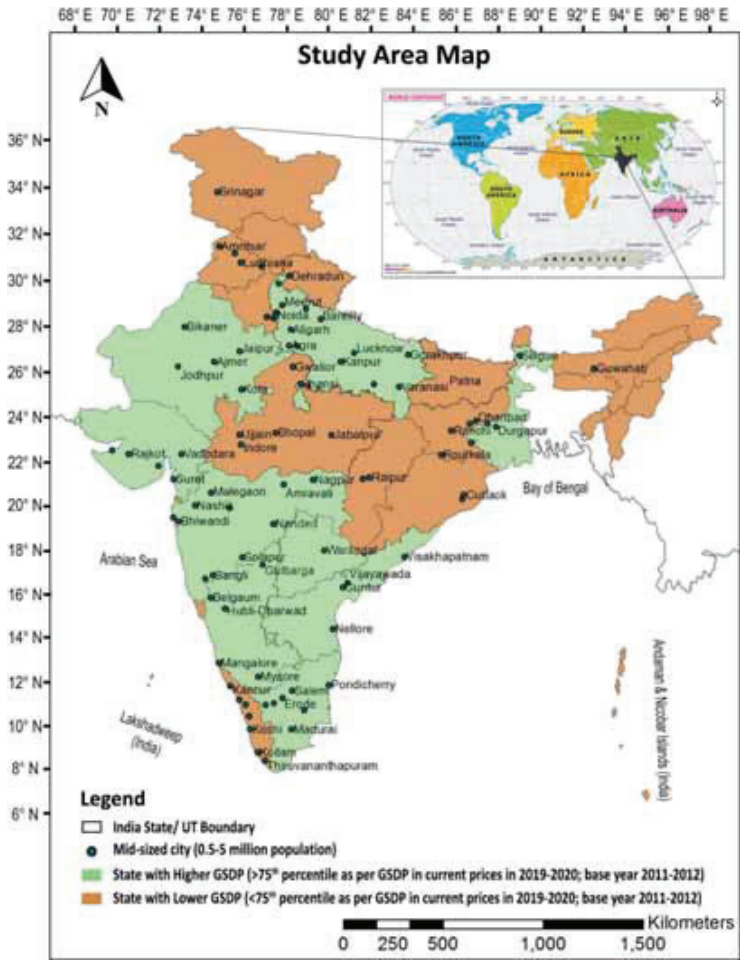

Fig. 1: Geographic location of the study area in India (Census of India, 2011)

The expansion of municipal area in India occurs after a detailed analysis of the population growth in the city and nearby areas, and land requirements for future development purposes. Therefore, details of the municipal area (decadal urban expansion rate) and the associated population (population growth rate) gathered from the Census of India were used as a variable to investigate the urban growth in the eighty-eight mid-sized Indian cities (Census of India, 2011). Overall, the Decadal Urban Expansion Rate (DUER) and Decadal Population Growth Rate (PR) indices were employed to monitor and analyze the urban growth pattern in mid-sized Indian cities (Peng *et al.,* 2015). UER measures the rate of urban expansion by quantifying the rise in the extent of municipal area within a decade was computed using Eq. 1 (Chettry, 2023a).

$$UER = \frac{UA_b - UA_a}{UA_a} \times 100\% \quad (1)$$

where UER is the decadal urban expansion rate, UA_a is the urban area in the a^{th} year (km^2), and UA_b is the urban area in the b^{th} year (km^2). PR measures the rate of population growth of an urban area within a decade was computed using Eq. 2 (Shahfahad *et al.,* 2020). These indices can effectively understand the temporal dynamics of urban growth occurring in each city.

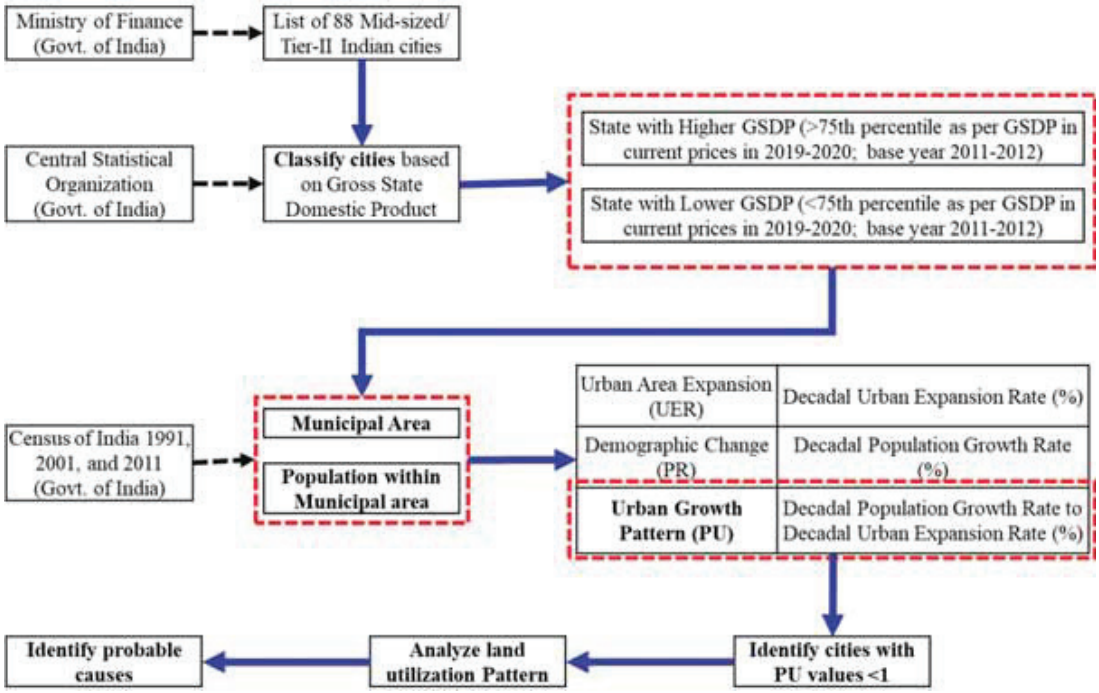

Fig. 2: Methodology adopted in this research

$$PR = \frac{P_b - P_a}{P_a} \times 100\% \quad (2)$$

$$PU = \frac{PR}{UER} \quad (3)$$

where PR is the decadal population growth rate, Pa is the total population in the a^{th} year, P_b is the total population in the b^{th} year, PU is the decadal population growth to urban expansion ratio, and UER is the decadal urban expansion rate.

Further population growth to urban expansion ratio (PU), i.e., a ratio of PR to UER was computed using Eq. 3 (Chen *et al.,* 2008; Dempsey, 2010; Chen *et al.,* 2014), provides an insight into the pattern of land utilization within municipal areas to manage rising population during the urban growth process. PU value less than 1 signifies the spatial expansion of municipal area is rapid compared to the rise in population within a decade. Such a pattern of urban growth is primarily due to inefficient land utilization and, in the future, it may lead to sprawl-like conditions (Akubia and Bruns 2019). Hence, if a PU value is less than 1, it signifies the prevalence of urban sprawl while a PU value of more than 1 signifies the occurrence of dense urban growth. Overall, PU assists in identifying whether the urban growth pattern in a city is towards sprawl or compact.

RESULTS AND DISCUSSION

The decadal UER and PR values from 1971 to 2011 in the mid-sized cities from the states with higher GSDP (>75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012) are presented in Table 2. It was observed that during 1971-1981, Ajmer exhibited the highest decadal urban expansion growth rate, i.e., 82%, Siliguri (75%), Tirupur (73%), and Nellore (72%), followed by other remaining cities.

During 1981-1991, highest UER was observed in Nanded-Waghala (72%), Aurangabad (71%), Bareilly (70%), Visakhapatnam (69%), Meerut (67%) and followed by other remaining cities. Further during 1991-2001, highest UER was observed in Solapur (81%), Moradabad (59%), Firozabad (58%), Jaipur (55%) and followed by other remaining cities. Lastly

Table 1: List of states with higher and lower GSDP (Reserve Bank of India, 2023)

S.No.	States with higher GSDP (>75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012)		States with lower GSDP (<75th percentile as per GSDP in current prices in 2019-2020; base year 2011-2012)	
	State/ UT (Mid-sized City)	GSDP in crores	State/ UT (Mid-sized City)	GSDP in crores
1	Maharashtra (Amravati, Aurangabad, Bhiwandi, Kolhapur, Malegaon, Nagpur, Nanded-Waghala, Nashik, Sangli, Solapur, and Vasai-Virar city)	2818555	Madhya Pradesh (Gwalior, Indore, Bhopal, Ujjain, and Jabalpur)	937405
2	Tamil Nadu (Coimbatore, Erode, Madurai, Salem, Tiruchirappalli, and Tirupur)	1797229	Kerala (Kozhikode, Kochi, Malappuram, Kannur, Kollam, Thiruvananthapuram, and Thrissur)	854689
3	Uttar Pradesh (Agra, Allahabad, Aligarh, Bareilly, Firozabad, Ghaziabad, Gorakhpur, Jhansi, Kanpur, Lucknow, Meerut, Moradabad, Noida, Saharanpur, and Varanasi)	1687818	Delhi	830872
4	Gujarat (Bhavnagar, Jamnagar, Rajkot, Surat, and Vadodara)	1630240	Haryana (Faridabad and Gurgaon)	780612
5	Karnataka (Belgaum, Gulbarga, Hubli-Dharwad, Mangalore, and Mysore)	1628928	Bihar (Patna)	594016
6	West Bengal (Durgapur, Siliguri, Asansol, Barddhaman)	1207823	Odisha (Cuttack, Bhubaneshwar, and Rourkela)	547959
7	Rajasthan (Ajmer, Bikaner, Jaipur, Jodhpur, and Kota)	998999	Punjab (Amritsar, Jalandhar, and Ludhiana)	539687
8	Andhra Pradesh (Vijayawada, Visakhapatnam, Nellore, and Guntur)	971224	Chhattisgarh (Durg-Bhilai and Raipur)	344955
9	Telangana (Warangal)	957207	Assam (Guwahati)	335238
10			Jharkhand (Dhanbad, Jamshedpur, Ranchi, and Bokaro)	321157
11			Uttarakhand (Dehradun)	253666
12			Jammu and Kashmir (Srinagar and Jammu)	170382
13			Himachal Pradesh	162816
14			Goa	74828
15			Tripura	55857
16			Chandigarh (Chandigarh)	43674
17			Puducherry (Puducherry)	37959
18			Meghalaya	34716
19			Manipur	31790
20			Sikkim	30809
21			Nagaland	29536
22			Arunachal Pradesh	28046
23			Mizoram	25149
24			Andaman & Nicobar Islands	9719

during 2001-2011, highest UER was observed in Vasai-Virar city (77%), Jhansi (66%), Kota (57%) and followed by other remaining cities. Overall, highest UER during 1971-2011 was observed in Vasai-Virar city (92%) followed by Solapur (87%), Nellore (86%), Meerut (85%), Surat (85%), Bhiwandi (84%), Ghaziabad (83%), and Visakhapatnam (82%). Highest decadal population growth rate, i.e., PR during 1971-1981 was exhibited by Siliguri (58%), Bhiwandi (53%), Ghaziabad (52%), Aurangabad (50%) and followed by other remaining cities. During 1981-1991, highest PR was observed in Vasai-Virar city (63%), Bhiwandi (55%), Aurangabad (48%) and followed by other remaining cities. Further during 1991-2001, highest PR was observed in Vasai-Virar city (58%), Noida (52%), Ghaziabad (47%), Surat (46%) and followed by other remaining cities. Lastly during 2001-2011, highest PR was observed in Vasai-Virar city (58%), Noida (52%), Ghaziabad (41%) and followed by other remaining cities. Overall, highest PR during 1971-2011 was observed in Vasai-Virar city (95%) followed by Ghaziabad (92%), Bhiwandi (89%), Surat (89%), Aurangabad (87%), Nashik (84%), and Siliguri (81%). The decadal UER and PR from 1971 to 2011 for the mid-sized cities from the states with lower GSDP (<75th percentile as per GSDP in current prices

Table 2: UER and PR values of mid-sized Indian cities from the state with higher GSDP

S. No.	Mid-sized cities from the states with higher GSDP (>75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012)	Decadal Urban Expansion Rate (UER)					Decadal Population Growth Rate (PR)				
		1971 -81	1981 91	1991 -2001	2001 -11	1971-2011	1971 -81	1981 91	1991 -2001	2001 -11	1971-2011
1	Amravati	0%	56%	0%	0%	56%	25%	30%	23%	15%	66%
2	Aurangabad	0%	71%	0%	0%	71%	50%	48%	34%	26%	87%
3	Bhiwandi	57%	64%	0%	0%	84%	53%	55%	37%	16%	89%
4	Kolhapur	0%	0%	0%	0%	0%	24%	16%	18%	10%	53%
5	Malegaon	0%	0%	0%	0%	0%	22%	28%	16%	13%	59%
6	Nagpur	0%	0%	0%	0%	0%	29%	25%	21%	15%	64%
7	Nanded-Waghala	0%	72%	5%	21%	79%	34%	38%	28%	22%	77%
8	Nashik	23%	61%	0%	0%	69%	36%	45%	39%	28%	84%
9	Sangli	24%	2%	28%	0%	46%	25%	27%	19%	13%	62%
10	Solapur	8%	23%	81%	0%	87%	23%	17%	29%	8%	58%
11	Vasai-Virar city	3%	46%	32%	77%	92%	28%	63%	58%	58%	95%
12	Coimbatore	2%	0%	0%	0%	2%	20%	14%	12%	11%	46%
13	Erode	-1%	1%	0%	0%	0%	26%	11%	-6%	4%	33%
14	Madurai	2%	0%	9%	0%	12%	23%	13%	-1%	9%	38%
15	Salem	12%	-6%	12%	0%	19%	20%	10%	21%	16%	52%
16	Tiruchirappalli	5%	14%	24%	0%	38%	17%	15%	14%	11%	47%
17	Tirupur	73%	0%	-60%	0%	56%	31%	30%	32%	22%	75%
18	Agra	0%	49%	0%	0%	49%	15%	22%	30%	20%	63%
19	Allahabad	0%	0%	1%	10%	10%	20%	22%	19%	12%	56%
20	Aligarh	-1%	0%	16%	0%	15%	21%	33%	28%	23%	71%
21	Bareilly	11%	70%	0%	0%	74%	28%	28%	18%	21%	66%
22	Firozabad	46%	7%	58%	-39%	71%	35%	23%	38%	28%	78%
23	Ghaziabad	42%	6%	51%	34%	83%	52%	44%	47%	41%	92%
24	Gorakhpur	20%	64%	3%	0%	72%	26%	38%	19%	8%	66%
25	Jhansi	24%	5%	16%	66%	79%	30%	23%	25%	16%	66%
26	Kanpur	0%	0%	0%	0%	0%	22%	21%	27%	8%	58%
27	Lucknow	15%	62%	0%	11%	71%	18%	41%	26%	22%	73%
28	Meerut	54%	67%	0%	0%	85%	34%	40%	29%	18%	77%
29	Moradabad	0%	0%	59%	-18%	52%	21%	22%	31%	28%	69%
30	Noida			0%	2%	2%			52%	52%	77%
31	Saharanpur	0%	0%	2%	45%	46%	24%	21%	18%	35%	68%
32	Varanasi	9%	1%	6%	-14%	3%	18%	23%	14%	8%	50%
33	Bhavnagar	0%	0%	0%	-69%	-69%	27%	24%	21%	14%	62%
34	Jamnagar	12%	1%	0%	-4%	10%	29%	19%	26%	-5%	56%
35	Rajkot	13%	31%	4%	5%	46%	32%	31%	34%	25%	77%
36	Surat	47%	19%	49%	33%	85%	47%	39%	46%	38%	89%

Continued Table 2: UER and PR values of mid-sized Indian cities from the state with higher GSDP

S. No.	Mid-sized cities from the states with higher GSDP (>75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012)	Decadal Urban Expansion Rate (UER)					Decadal Population Growth Rate (PR)				
		1971 -81	1981 91	1991 -2001	2001 -11	1971-2011	1971 -81	1981 91	1991 -2001	2001 -11	1971-2011
37	Vadodara	28%	0%	12%	26%	53%	36%	29%	23%	20%	72%
38	Belgaum	66%	6%	10%	0%	71%	30%	16%	18%	18%	61%
39	Gulbarga	51%	31%	25%	0%	74%	34%	28%	27%	21%	73%
40	Hubli-Dharwad	5%	0%	11%	0%	15%	28%	19%	18%	17%	60%
41	Mangalore	55%	34%	3%	3%	72%	30%	22%	14%	14%	60%
42	Mysore	39%	-4%	35%	0%	58%	24%	20%	22%	15%	60%
43	Asansol	28%	52%	20%	-2%	71%	22%	30%	4%	16%	56%
44	Durgapur	0%	0%	0%	0%	0%	34%	27%	14%	13%	64%
45	Siliguri	75%	0%	-47%	0%	63%	58%	37%	23%	8%	81%
46	Ajmer	82%	-9%	-8%	-2%	78%	30%	7%	18%	10%	51%
47	Bikaner	19%	55%	0%	-7%	61%	27%	31%	21%	18%	68%
48	Jaipur	-23%	4%	55%	0%	47%	37%	33%	35%	24%	79%
49	Jodhpur	0%	4%	-9%	68%	66%	37%	24%	22%	17%	69%
50	Kota	36%	0%	2%	57%	73%	41%	33%	24%	30%	79%
51	Guntur	0%	0%	34%	0%	34%	27%	22%	8%	21%	58%
52	Nellore	72%	0%	45%	10%	86%	44%	25%	22%	19%	73%
53	Vijayawada	5%	-18%	27%	-37%	-11%	35%	25%	25%	9%	67%
54	Visakhapatnam	2%	69%	5%	37%	82%	40%	42%	22%	22%	79%
55	Warangal	0%	1%	41%	-38%	19%	38%	25%	20%	9%	66%

in 2019-2020; base year 2011-2012) is presented in Table 3. It was observed that during 1971-1981, Faridabad exhibited highest decadal urban expansion growth rate, i.e., 86%, Thrissur (77%), Ludhiana (62%) and followed by other remaining cities. During 1981-1991, highest UER was observed in Patna (47%), Malappuram (42%), Thiruvananthapuram (42%) and followed by other remaining cities. Further during 1991-2001, highest UER was observed in Raipur (44%), Gurgaon (37%), Kozhikode (35%) and followed by other remaining cities. Lastly during 2001-2011, highest UER was observed in Gurgaon (72%), Jamshedpur (41%) and followed by other remaining cities. Overall, highest UER during 1971-2011 was observed in Gurgaon (91%) followed by Faridabad (87%), Guwahati (80%), Thrissur (79%), and Ludhiana (74%). Highest decadal population growth rate, i.e., PR during 1971-1981 was exhibited by Faridabad (63%), Thrissur (59%), Bokaro Steel City (58%), Bhubaneswar (52%) and followed by other remaining cities. During 1981-1991, highest PR was observed in Bhubaneswar (47%), Faridabad (46%), Malappuram (45%), Ludhiana (42%) and followed by other remaining cities. Further during 1991-2001, highest UER was observed in Faridabad (42%), Gurgaon (40%), Bhubaneswar (36%) Raipur (36%) and followed by other remaining cities. Lastly during 2001-2011, highest UER was observed in Gurgaon (73%), Raipur (30%) and followed by other remaining cities. Overall, the highest PR during 1971-2011 was observed in Gurgaon (93%) followed by Faridabad (91%), Bhubaneswar (87%), and Raipur (80%).

The mid-sized Indian cities from the higher GSDP states with PU values less than 1 are presented in Table 4. During 1971-1981, the city with the lowest PU value was Ajmer (0.36) followed by Tirupur

Table 3: UER and PR values of mid-sized Indian cities from the states with lower GSDP

S. No.	Mid-sized cities from the states with lower GSDP (<75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012)	Decadal Urban Expansion Rate (UER)					Decadal Population Growth Rate (PR)				
		1971-81	1981-91	1991-2001	2001-11	1971-2011	1971-81	1981-91	1991-2001	2001-11	1971-2011
1	Gwalior		0%	-74%	4%	-67%	25%	22%	16%	22%	61%
2	Indore	48%	31%	-3%	-22%	55%	32%	25%	26%	23%	71%
3	Bhopal	57%	0%	5%	-4%	57%	43%	37%	27%	19%	79%
4	Ujjain	0%	20%	0%	0%	19%	26%	22%	16%	16%	60%
5	Jabalpur	0%	-13%	-15%	-1%	-32%	31%	13%	20%	10%	57%
6	Kozhikode	0%	0%	35%	-51%	2%	15%	6%	18%	-19%	23%
7	Kannur	0%	0%	0%	0%	0%	9%	7%	-2%	-12%	3%
8	Kochi	0%	13%	18%	-41%	0%	14%	12%	12%	-9%	27%
9	Kollam	10%	35%	11%	0%	48%	21%	32%	14%	-4%	52%
10	Malappuram	0%	42%	0%	0%	42%	20%	45%	16%	14%	68%
11	Thiruvananthapuram	7%	42%	5%	-20%	39%	16%	31%	11%	-14%	41%
12	Thrissur	77%	9%	2%	0%	79%	59%	13%	10%	0%	68%
13	Faridabad	86%	0%	10%	3%	87%	63%	46%	42%	25%	91%
14	Gurgaon	36%	19%	37%	72%	91%	43%	29%	40%	73%	93%
15	Patna	-26%	47%	1%	-1%	33%	42%	15%	33%	15%	72%
16	Cuttack	7%	37%	16%	0%	51%	30%	28%	24%	12%	66%
17	Bhubaneswar	30%	26%	7%	0%	52%	52%	47%	36%	23%	87%
18	Rourkela	8%	0%	-5%	-34%	-28%	42%	8%	-9%	1%	42%
19	Amritsar	59%	0%	15%	0%	66%	24%	16%	28%	13%	60%
20	Jalandhar	22%	1%	21%	-1%	39%	27%	20%	28%	18%	66%
21	Ludhiana	62%	18%	15%	0%	74%	34%	42%	25%	14%	75%
22	Durg-Bhilai Nagar	-12%	26%	21%	-6%	31%	44%	30%	20%	12%	73%
23	Raipur		10%	44%	26%	63%	39%	25%	36%	30%	80%
24	Guwahati			0%	1%	80%			28%	15%	79%
25	Dhanbad	2%	-4%	5%	0%	2%	33%	15%	22%	11%	61%
26	Jamshedpur	-6%	-1%	0%	41%	37%	22%	5%	20%	9%	46%
27	Ranchi	49%	0%	0%	-1%	49%	48%	18%	29%	21%	76%
28	Bokaro Steel City	0%	-3%	0%	0%	-3%	58%	33%	15%	5%	77%
29	Dehradun	0%	20%	26%	24%	54%	21%	25%	34%	25%	71%
30	Jammu	-17%			34%	52%	26%			9%	69%
31	Srinagar	52%			19%	65%	30%			21%	65%
32	Chandigarh	16%	12%	2%	23%	44%	45%	27%	29%	16%	76%
33	Puducherry	3%	0%	16%	-19%	3%	18%	20%	17%	0%	45%

(0.42), Belgaum (0.45), Mangalore (0.54), and other remaining cities. During 1981-1991, the lowest PU value was observed in Bareilly (0.40) followed by Agra (0.44), Nanded-Waghala (0.52), Amravati (0.53), Bikaner (0.56), Asansol (0.57) and other remaining cities. Further during 1991-2001, the city with the lowest PU value was Madurai (-0.11) followed by Asansol (0.20), Guntur (0.23), Solapur (0.35), Nellore

Table 4: PU values of mid-sized Indian cities from the state with higher GSDP

S. No.	Mid-sized cities from the states with higher GSDP (>75th percentile as per GSDP in current prices in 2019-2020; the base year 2011-2012)	PU (Decadal Population Growth Rate to Decadal Urban Expansion Rate)				
		1971 -81	1981 -91	1991 -2001	2001 -11	1971 -2011
1	Amravati		0.53			
2	Aurangabad		0.67			
3	Bhiwandi	0.92	0.85			
4	Nanded-Waghala		0.52			0.97
5	Nashik		0.73			
6	Sangli			0.67		
7	Solapur		0.74	0.35		0.67
8	Vasai-Virar				0.75	
9	Madurai			-0.11		
10	Tiruchirappalli			0.58		
11	Tirupur	0.42				
12	Agra		0.44			
13	Bareilly		0.40			0.89
14	Firozabad	0.76		0.65		
15	Ghaziabad			0.92		
16	Gorakhpur		0.59			0.92
17	Jhansi				0.24	0.84
18	Lucknow		0.66			
19	Meerut	0.63	0.59			0.91
20	Moradabad			0.52		
21	Saharanpur				0.77	
22	Surat			0.93		
23	Vadodara				0.77	
24	Belgaum	0.45				0.86
25	Gulbarga	0.66	0.90			0.99
26	Mangalore	0.54	0.64			0.83
27	Mysore	0.61		0.62		
28	Asansol	0.78	0.57	0.20		0.79
29	Siliguri	0.77				
30	Ajmer	0.36				0.65
31	Bikaner		0.56			
32	Jaipur			0.63		
33	Kota				0.52	
34	Guntur			0.23		
35	Nellore	0.61		0.48		0.85
36	Vijayawada			0.92		
37	Visakhapatnam		0.60		0.60	0.96
38	Warangal			0.48		

Table 5: PU values of mid-sized Indian cities from the states with lower GSDP

S.No.	Mid-sized cities from the states with lower GSDP (>75th percentile as per GSDP in current prices in 2019-2020; base year 2011-2012)	PU (Decadal Population Growth Rate to Decadal Urban Expansion Rate)				
		1971 -81	1981 -91	1991 -2001	2001 -11	1971 -2011
1	Indore	0.67	0.81			
2	Bhopal	0.75				
3	Kozhikode			0.51	0.37	
3	Kochi		0.92	0.67	0.22	
4	Kollam		0.91			
5	Thiruvananthapuram		0.74		0.70	
6	Thrissur	0.77				0.86
7	Faridabad	0.73				
8	Patna		0.32			
9	Amritsar	0.41				0.91
10	Ludhiana	0.55				
11	Durg-Bhilai Nagar			0.95		
12	Raipur			0.82		
13	Guwahati					0.99
14	Jamshedpur				0.22	
15	Ranchi	0.98				
16	Jammu				0.26	
17	Srinagar	0.58				
18	Chandigarh				0.70	
19	Puducherry				0	

(0.48), Warangal (0.48) and other remaining cities. Lastly, during 2001-2011, the city with the lowest PU value was Jhansi (0.24) followed by Kota (0.52), Visakhapatnam (0.60), and other remaining cities. Overall, the lowest PU value during 1971-2011 was observed in Ajmer (0.65) followed by Solapur (0.67), Asansol (0.79), Mangalore (0.83), Jhansi (0.84), Nellore (0.85), Belgaum (0.86), Bareilly (0.89) and other remaining cities.

The mid-sized Indian cities from the lower GSDP states with PU values of less than 1 are presented in Table 5. During 1971-1981, the city with the lowest PU value was Amritsar (0.41) followed by Ludhiana (0.55), Srinagar (0.58), and other remaining cities. During 1981-1991, the lowest PU value was observed in Patna (0.32) followed by Thiruvananthapuram (0.74), Indore (0.81), and other remaining cities. During 1991-2001, the lowest PU value was observed in Kozhikode (0.51) followed by Kochi (0.67) and other remaining cities. Lastly, during 2001-2011, the city with the lowest PU value was Kochi (0.22), Jamshedpur (0.22) followed by Jammu (0.26), Kozhikode (0.37), and other remaining cities. Overall, the lowest PU value during 1971-2011 was observed in Thrissur (0.86) followed by Amritsar (0.91), and Guwahati (0.99).

The findings highlight a nuanced pattern within mid-sized Indian cities from higher GSDP states, where cities such as Ajmer, Tirupur, Belgaum, and Mangalore consistently exhibit PU values below 1 across different decades. This suggests an ongoing trend towards urban sprawl in these economically more prosperous regions. Ajmer, with the lowest PU value of 0.36 during 1971-1981, exemplifies an early instance of urban sprawl. Similar pattern of urban growth in these cities has been found in previous

studies based on land cover change analysis (Lakra and Sharma, 2019; Elangovan and Krishnaraaju, 2023). Despite economic advancements, these cities face challenges in optimizing land use, potentially leading to future sprawl-like conditions. Similarly, mid-sized cities from lower GSDP states, including Amritsar, Patna, and Kozhikode, exhibit PU values less than 1, pointing to a similar trend of urban sprawl. Thrissur consistently maintains the lowest PU value (0.86) overall, emphasizing a prolonged pattern of inefficient land utilization in this region. The significance of these findings lies in the implications for urban planning and policy interventions. The identification of cities experiencing urban sprawl highlights the urgency of adopting measures to promote sustainable and efficient land use. Urban planners and policymakers can draw upon these findings to formulate strategies as per the specific challenges faced by cities in different economic contexts. Implementing land-use regulations, encouraging mixed-use development, and investing in infrastructure that supports compact urban growth can be crucial steps toward mitigating the adverse effects of urban sprawl. The significant driving factors that triggered urban growth in the selected Indian cities are government policies and schemes, industrial growth, GSDP, climatic conditions and terrains, social profile, transportation, infrastructure, and coordination between the central and state governments. After the liberalization of the Indian economy during the early 1990s, growth in economic opportunities started pouring into India and triggered urban growth in mid-sized Indian cities. This led to the creation of new cities such as Gurgaon, and Noida, and the expansion of existing cities towards the peripheral areas (Sanyal *et al.,* 2010). The reforms in industrial sectors were introduced to reduce trade barriers. Overall, the urban growth was prominently due to the huge growth momentum experienced by mid-sized Indian cities combined with unplanned urbanization. It led to urban expansion towards the periphery in the form of urban sprawl. Such an urban growth pattern is evident through the built-up growth in low-density rural areas. Growth in the GSDP of states due to several reforms and policies positively correlated with land conversion, i.e., an increase in an urban area (Pandey and Seto, 2015). It also shows that the combined service and manufacturing sector had a higher share in the GSDP of states which experienced higher urban growth due to agricultural land loss. The population in these cities increased due to natural growth and migration from nearby towns and cities to seek a better quality of life and improved living standards. Further, improved life expectancy rates, lower infant and maternal mortality rates during birth, and child mortality rates led to high population growth. Better transportation facilities and infrastructure up-gradation led to the growth in employment opportunities, thereby attracting migrants (Chandrasekhar and Sharma, 2015). Moreover, the political and administrative interventions directed through the master plan significantly affect the urban growth within the city (Rath *et al.,* 2022). All these factors cumulatively led to the expansion of mid-sized Indian cities. The introduction of policies and schemes by the Government of India post the liberalization of the Indian economy in 1991 has played a pivotal role in catalyzing rapid urban growth, as depicted in Fig. 3. The post-liberalization era witnessed a significant policy framework designed to stimulate industrial growth through various measures. These initiatives included promoting investment in research and development, embracing new technologies, fostering the development of the capital market, enhancing competitiveness, and encouraging entrepreneurship for the overall benefit of the public. The cornerstone

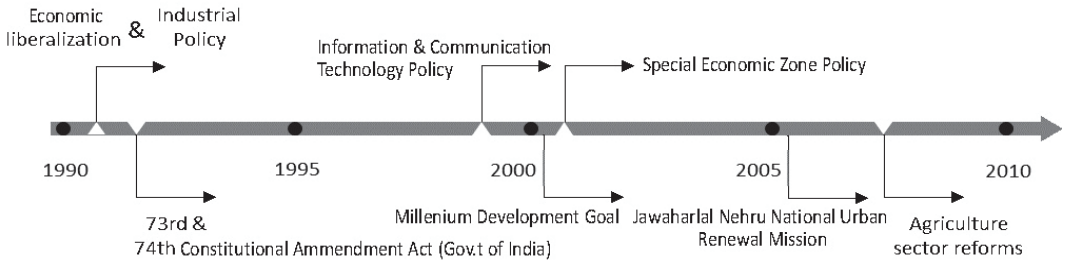

Fig. 3: Key policies undertaken post-liberalization of the Indian economy in 1991

of this transformative phase was the New Industrial Policy of 1991, which, along with other complementary policies, aimed at the liberalization of activities previously reserved for the public sector. These policy interventions have contributed to the dynamic urbanization observed in Indian cities, fostering economic development and shaping the urban landscape in the post-1991 period. The multifaceted approach of these policies has played a crucial role in promoting a vibrant and competitive urban environment, aligning with the broader goals of economic growth and development (Neisiani *et al.,* 2016).

Further, the 73rd and 74th Constitutional Amendment Act (CAA) by the Govt. of India was aimed to promote effective governance and improve the delivery of urban infrastructure and other basic services. However, a complete devolution of powers to the local government as per the CAA is yet to be completed in all the states. Significant steps were taken to promote Information and Communications Technology (ICT) with a strong focus on software development for export and the telecommunication sector. It was further enhanced by policy towards deregulation of Foreign Direct Investment (FDI). Under the automatic route, FDI up to 100 percent was allowed for most manufacturing activities in Special Economic Zones (SEZs). In India, most of the SEZs are located in peripheral areas under non-urban jurisdiction; hence no stringent rules are framed to check the ribbon and scatter growth occurring in these areas. Various social schemes and policies focusing on urban areas further raised the quality of living and fostered rapid population growth. Key social schemes initiated from 1991 to 2011 were the Twenty-point Programme, Affordable Housing for All, and the Jawaharlal Nehru National Urban Renewal Mission. Urban transport policy promoted safe, affordable, and efficient public transportation for increased mobility of urban populations and lower the impact of increasing vehicles on air quality. National Highway Development Project, Delhi-Mumbai Industrial Corridor, and Amritsar-Kolkata Industrial Corridor further led to the creation of small towns and villages and triggered urban expansion in the periphery of existing cities. Such cities expanded in the form of ribbon development along these routes and major junctions (Ministry of Environment and Forests and Government of India, 2011).

CONCLUSION

Mid-sized cities in India have been experiencing rapid urban growth due to the saturation of large cities. Such rapid development has triggered haphazard urban growth in these cities. However, there are lack of studies that attempts to comprehensively analyze the urban growth pattern in these cities for the preparation of strategies to mitigate such adverse conditions. Moreover, the 11th SDG of the 2030 Agenda for Sustainable Development emphasizes the promotion of sustainable cities and communities through urban planning strategies. Therefore, this study investigated the urban growth patterns across eighty-eight mid-sized Indian cities from 1971 to 2011, using census datasets. Overall, the results from states with higher GSDP revealed inefficient land utilization for urban growth, indicated by a PU (Population-to-Urban Expansion) ratio of less than 1 during 1971-2011 in thirteen (24%) out of fifty-five mid-sized Indian cities. Prominent mid-sized cities from states with higher GSDP that exhibited a PU less than 1 during 1971-2011 included Ajmer (0.65), Solapur (0.67), Asansol (0.79), Mangalore (0.83), Jhansi (0.84), Nellore (0.85), Belgaum (0.86), Bareilly (0.89), and the remaining five cities. In contrast, results extend to other countries facing similar economic disparities, emphasizing the importance of strategic planning to manage urbanization effectively. A global approach in future studies could involve comparative analyses with mid-sized cities in other countries to identify commonalities and unique regional drivers affecting land utilization efficiency. The major drivers for urban growth in mid-sized Indian cities include government policies and schemes, industrial growth, a rise in GSDP, climatic conditions and terrains, social profile, transportation, and infrastructure. This study has some limitations, such as the unavailability of data regarding the built-up area of all mid-sized Indian cities; hence, the decadal expansion of the municipal area obtained from the Census of India was used as a variable. Urban growth occurring outside the municipal boundary is not considered in this study, and there is no recent data available as the last census survey was conducted in 2011. The government has introduced various popular schemes and policies in India to channel urban growth in the right direction, including Smart City, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), and Heritage City Development and Augmentation

Yojana (HRIDAY). These schemes might impact the pattern of urban growth; therefore, further monitoring of urban expansion in cities with a PU of less than 1 from 1971-2011 is necessary to investigate its effectiveness. Future research could also explore the applicability of the methodology in diverse international contexts, contributing to a broader understanding of urbanization challenges and sustainable development.

AUTHOR CONTRIBUTIONS

V. Chettry performed the literature review, experimental design, analyzed and interpreted the data, prepared the manuscript text, and manuscript edition.

ACKNOWLEDGEMENT

The author thanks the editor and the anonymous reviewers who reviewed this manuscript. The author is grateful to IIT(BHU) Varanasi for providing the necessary infrastructure to carry out this research work.

CONFLICTS OF INTEREST

The authors declare that there is not any conflict 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 have been completely observed by the authors.

ABBREVIATIONS

AER	Annual Expansion Rate
AGR	Annual Growth Rate
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
CAA	Constitutional Amendment Act
FDI	Foreign Direct Investment
GSDP	Gross State Domestic Product
HRIDAY	Heritage City Development and Augmentation Yojana
ICT	Information and Communications Technology
ISA	Impervious Surface Area
LCR	Land Consumption Rate
PR	Population Growth Rate
PU	Urban Growth Character
SDG	Sustainable Development Goal
SEZ	Special Economic Zones
AAUER	Average Annual Urban Expansion Rate
UER	Urban Expansion Rate
USA	United States of America
UT	Union Territory

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HOW TO CITE THIS ARTICLE

Chettry, V., (2024). Dynamics of urban growth in eighty-eight mid-sized Indian cities using census data. Int. J. Hum. Capital Urban Manage., 9(3): 521-536.

DOI: 10.22034/IJHCUM.2024.03.11

URL: https://www.ijhcum.net/article_711517.html

Int. J. Hum. Capital Urban Manage., 9(3): 537-552, Summer 2024

International Journal of Human Capital in Urban Management
(IJHCUM)

Homepage: http://www.ijhcum.net/

ORIGINAL RESEARCH PAPER

Applying Six Sigma methodology to improve performance in organizations

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ARTICLE INFO

Article History:
Received 23 December 2023
Revised 27 February 2024
Accepted 29 March 2024

Keywords:
Analytic hierarchy process (AHP)
Balance Scorecard (BSC)
Six Sigma Methodology
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

ABSTRACT

BACKGROUND AND OBJECTIVES: Six Sigma is a common methodology that has been applied successfully in many organizations leading to sustainable performance improvements in products and services. However, the applied methodologies have not paid attention to Multi-Criteria decision-making models, clustering algorithms, and Balance scorecard models. The purpose of this model is to apply the six-sigma methodology in Tehran Municipality and show how the Balance scorecard model, clustering algorithm, Analytic Hierarchy Process, and Technique for Order of Preference by Similarity to Ideal Solution can be applied in the methodology.

METHODS: Define, Measure, Analyze, Improve, and Control as a common methodology of Six Sigma is applied in Tehran Municipality. Several unique elements that exist in Tehran Municipality are identified and categorized based on the Balance scorecard model into indexes, goals, and perspectives. Also, the Analytic Hierarchy Process for weight extraction and Technique for Order of Preference by Similarity to the Ideal Solution for ranking is applied. The improvement strategies are created based on the Six Sigma tolerances.

FINDINGS: The findings show that the methodology can be elevated by a balanced scorecard, Analytic Hierarchy Process, and Technique for Order of Preference by Similarity to Ideal Solution. This formulation is done and applied in Tehran Municipality and can be used in other organizations for conducting improvement strategies. Based on the arbitrary data, the best district of Tehran city is district 9 with 89.75 percent and the worst is district 18 with a 10.12 percent score. Also, Wards and K-mean clustering algorithms and Six Sigma control limits are used to cluster the districts into superior, somehow superior, moderate, somehow inferior, and inferior clusters based on their performance.

CONCLUSION: This manuscript helps to understand the way of integrating the methodology, Balance scorecard, analytic hierarchy process, technique for order of preference by similarity to an ideal solution, and Six Sigma tolerances for sustainable improvement of Tehran Municipality. The proposed formulation can be used in any organization to reach sustainable improvement.

DOI: 10.22034/IJHCUM.2024.03.12

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
37	0	11

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Note: Discussion period for this manuscript open until October 1, 2024 on IJHCUM website at the "Show Article.

INTRODUCTION

Quality management has long been established as an important strategy for achieving competitive advantage. It has a lot of tools to reach excellence. Statistical quality control, kaizen, Quality Function Deployment, and Six Sigma are some of the widely used tools that help organizations improve their operations (Chakrabarty and Chuan Tan, 2007). Six Sigma is a methodology that can applied to both manufacturing and services (Chakrabarty and Chuan Tan, 2007). It tries to make a process free of error (3.4 defects per million opportunities) and omit variations from the average amount of a process (Chakrabarty and Chuan Tan, 2007). Different definitions of Six Sigma are available in the literature: Six Sigma is a business strategy used to improve business profitability, and the effectiveness and efficiency of all operations to meet or exceed customer needs and expectations (Kwak and Anbari, 2006). Minitab describes Six Sigma as an information-driven methodology for reducing waste, increasing customer satisfaction, and improving processes, with a focus on financially measurable results (Goh, 2002). The root of Six Sigma is back to Frederick Gauss, who introduced the concept of a normal curve or a normal distribution (Chakrabarty and Chuan Tan, 2007). Walter Shewhart in 1992 introduced three sigma for measuring and controlling variation of a process, and he stated that if the output of a process went beyond this limit, then process intervention is needed (Chakrabarty and Chuan Tan, 2007). According to Three Sigma, a process yields 99.973 percent or a defect rate of 2,600 per. Define, Measure, Analyze, Improve, and Control (DMAIC) is a reputable methodology of Six Sigma (Chakrabarty and Chuan Tan, 2007). On the other hand, performance management is essential for each company to improve performance and achieve excellence (Tomaževič *et al.*, 2017). Organizations need an integrated model to identify opportunities and problems to help them improve their processes, achieve their goals, and make steps toward their missions and visions (Mendes *et al.*, 2012). So, the main questions here arise: How DMAIC methodology can be applied in an organization as a performance management tool? How Six Sigma control limits can be used to cluster the data? How Multi Criteria Decision Making (MCDM) techniques can be applied through the DMAIC methodology? How the Balanced Score Card (BSC) can be applied in DMAIC methodology? How BSC, MCDM, and clustering algorithms can be integrated by the DMAIC methodology to introduce a more complex methodology? A clustering algorithm can help the manager to divide obtained performance into different groups. In this way, they can easily find out the strengths and weaknesses of an organization and can conduct improvement strategies. Hierarchical clustering divides the data into some groups based on some distance ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). In this method, the clusters are not specified in advance but it uses dendrograms to define the number of clusters ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). A dendrogram is a tree representation plot that shows how clusters are distributed ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Agglomerative hierarchical clustering (bottom-up) and divisive hierarchical clustering (top-down) are two main hierarchical clustering algorithms ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). The distance measure is used to define similarity or dissimilarity between clusters ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). The Euclidean distance, the Manhattan distance, the Minkowski distance, and the Pearson sample correlation distance are the most common distance calculation methods ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Maximum or complete linkage clustering, minimum or single linkage clustering, mean or average linkage clustering, centroid linkage clustering, and Ward's minimum variance method are the most common agglomeration clustering methods ((Witten and James, 2013); (Hastie *et.al*, 2009); (Lantz, 2019)). Mostly, classifications are supervised learning but clustering is unsupervised learning methods (some clustering models are for both) (Veyssieres and Plant,1998). Clustering has descriptive goals but classification has predictive (Veyssieres and Plant,1998). Forming categories of entities and assigning individuals to the proper groups within it is the main duty of clustering methods (Veyssieres and Plant,1998). Ward's is one of the hierarchical clustering methods that compute sum-of-squares as a criterion in multivariate Euclidean space, producing groups that minimize within-group dispersion at each binary fusion (Murtagh and Legendre, 2014). K-mean partitioning is a common

partitioning clustering method that uses the total error sum of squares criterion (Murtagh and Legendre, 2014). The BSC first introduced by Kaplan and Norton (1992), is a framework that divides the main activities of an organization into four main perspectives: financial, customer, internal business process, and learning and growth. BSC provides coherent links between perspectives, goals, and KPIs. On the other hand, MCDM techniques are mathematical tools that might be helpful to calculate the current performance of an organization. The Analytic Hierarchy Process (AHP), as proposed by (Saaty, 1987) which reduces complex decisions to a series of pairwise comparisons and also can extract weights of indexes is a common technique in MCDM to extract the weights. Hwang and Yoon (1981) developed a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for the first time. The Weighted Sum Model (WSM) which also named as Simple Additive Weighting model (SAW), the Weighted Product Model (WPM), AHP with some of its variants, the ELECTRE (Elimination and Choice Translating Reality; English translation from the French original) and the TOPSIS methods are the most common techniques in MCDM models (Triantaphyllou, 2000). Jabbarzadeh (2018) presented an application of the AHP and TOPSIS in project management for contractor selection. Esfandiari and Rizvandi (2014) presented an empirical investigation to rank different business development strategies for information technology improvement based on the TOPSIS method. Wang *et al.* (2009) proposed fuzzy hierarchical TOPSIS for supplier selection. Wang and Chang (2007) proposed an application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. Lin *et al.* (2008) proposed AHP and TOPSIS approaches in the customer-driven product design process. Chu (2002) proposed a fuzzy TOPSIS approach for selecting plant locations. Behzadian *et al.* (2012) surveyed TOPSIS applications. Meshram *et al.* (2020) presented the application of simple additive weights and TOPSIS in prioritizing watersheds. Afshari *et al.* (2010) presented a simple additive weighting approach to the personnel selection problem. Sahir *et al.* (2017) used a simple additive weighting method to determine the employee salary increase rate. Kaliszewski and Podkopaev (2016) introduced a Meta-model for multiple criteria decision analysis methods and proposed a framework for interpretations of rankings they produce by using simple additive weighting. Nurmalini and Rahim (2017) studied the approach of simple additive weighting for a decision support system. Chou *et al.* (2008) presented a fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes. Al-Harbi (2001) used an analytical hierarchy process to prioritize contractors of a project and select the best one to perform the project. Handfield *et al.* (2002) used the analytical hierarchy process and environmental criteria for supplier assessment. Partovi *et al.* (1990) showed the application of the analytical hierarchy process in different operation management areas like forecasting, supplier selection, facility location, choice of technology, product design, plant layout, maintenance frequency selection, and choice of logistic carrier. Palcic and Lalic (2009) used an analytical hierarchy process for selecting and evaluating projects. Fong and Choi (2000) used an analytical hierarchy process for contractor selection. Araujo *et al.* (2018) applied a two-stage approach of TOPSIS in public hospitals in 92 Rio de Janeiro municipalities. Mirfakhredini *et al.* (2013) proposed a model to assess the performance of sports organizations with BSC and TOPSIS. Azar *et al.* (2011) presented an integrated model with the BSC framework for supplier selection strategy. Kumar *et al.* (2020) prioritized attributes for successfully implementing agile manufacturing using a combined AHP and TOPSIS approach in the Indian manufacturing industry. Sehhat *et al.* (2015) have developed an evaluation model considering the indicators identified, in assessing seven insurance companies in the ranking and weighting of these criteria and companies, the AHP and TOPSIS techniques have been used. Yadav *et al.* (2018) used fuzzy AHP and TOPSIS for prioritizing solutions for Lean Six Sigma. Rathi *et al.* (2015) applied fuzzy TOPSIS for Six Sigma project selection in the automobile industry. Table 1 compares this study to the related literature.

Brilliant results can be obtained by aggregating quality management, strategic management, clustering algorithms, and MCDM models. DMAIC, a reputable methodology of Six Sigma, is a powerful tool for quality management. BSC is a significant tool for performance improvement in strategic management. AHP and TOPSIS both are widely used techniques of MCDM. K-mean and Wards are two

Table 1: Comparison of literature by study

Sources	Clustering algorithm	Six Sigma	BSC	TOPSIS/FTOPSIS	AHP/FAHP
Fong and Choi (2000)					✓
Al-Harbi (2001)					✓
Chu (2002)				✓	
Handfield *et al.* (2002)					✓
Palcic and Lalic (2009)			✓	✓	✓
Azar *et al.* (2011)					✓
Mirfakhredini *et al.* (2013)			✓	✓	
Esfandiari and Rizvandi (2014)				✓	✓
Sehhat *et al.* (2015)				✓	✓
Rathi *et al.* (2015)		✓		✓	
Araujo *et al.* (2018)				✓	
Jabbarzadeh (2018)				✓	✓
Yadav *et al.* (2018)		✓		✓	✓
Kumar *et al.* (2020)				✓	✓
This Study	✓	✓	✓	✓	✓

prominent clustering algorithms. To our knowledge, no study shows how DMAIC methodology can be integrated by BSC, AHP, and TOPSIS. So, this study has formulated the integration and shown how this can help organizations to conduct their improvement strategies more efficiently. Also, a clustering algorithm based on Six Sigma control limits is defined. Five performance clusters: superior, somehow superior, moderate, somehow inferior, and inferior are defined by Six Sigma control limits to categorize the districts. Finally, the proposed integration has been implemented at offices of plan monitoring, project control, and performance evaluation in planning, human capital development, and council affairs department at Tehran Municipality. The current study has been carried out in offices of plan monitoring, project control, and performance evaluation in planning, human capital development, and council affairs department at Tehran Municipality in Tehran in 2023.

MATERIALS AND METHODS

DMAIC methodology a well-known methodology of Six Sigma is applied. BSC is used to make a better and more hierarchical definition of indexes, goals, and perspectives. The weights of elements are calculated by AHP and TOPSIS is used to compute the rank of the districts in each element. In the define phase. A comprehensive explanation of the problem is necessary, and it is recommended to convene the deputies' agents to collectively identify the issue. The employment of BSC aids in elucidating the problem, and it is imperative to consider all the processes, inputs, outputs, outcomes, and associated impacts. It is imperative to establish clarity on the aspects of what to measure, how to measure, and the measurement system. The district's defined indexes, goals, perceptions, and final scores must be measured to ensure accurate evaluation. The AHP is utilized to determine the weights of the elements, while the TOPSIS is employed for the score calculation process. AHP involves a pairwise comparison matrix, where the criteria are compared using Saaty's 1-9 scale of pairwise comparisons (Saaty, 1987), as presented in Table 2.

All the criteria are given a score according to the comparison table in a pairwise comparison. The vector of weights $(W_1,..,W_n)$ related to A can be extracted by normalization of the geometric mean method. Let W_i denotes the weight of the element i in matrix A, Eq. 1 represents the geometric mean (Saaty, 1987):

Table 2: The scale of pairwise comparisons

Degree of Importance	Definition	Explanation
1	Equal importance	Two criteria have equal importance according to the objective.
2	Weak or slight	According to the objective, the first criterion has weak or slight importance to the second criterion.
3	Moderate importance	The first criterion has moderate importance to the second criterion according to the objective.
4	Moderate plus	Between 3 and 5
5	Strong importance	The first criterion has strong importance to the second criterion according to the objective.
6	Strong plus	Between 5 and 7
7	Very strong	The first criterion has very strong importance to the second criterion according to the objective.
8	Very, very strong	The first criterion is very important to the second criterion according to the objective.
9	Extreme importance	The first criterion has extremely strong importance to the second criterion according to the objective.

Table 3: Consistency ratio

Matrix size	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}, \quad i, j = 1, \ldots, n. \qquad (1)$$

Imagine C is an n-dimensional column vector describing the sum of the weighted values for the importance degrees of elements in A matrix, then: $C = [c_i]_{n*1} = A.W^T,\ i = 1, \ldots, n$. The consistency value can be represented by $CV = [cv_i]_{1*n}$ where $cv_i = \frac{c_i}{w_i},\ i = 1, \ldots, n$. The inconsistency index to evaluate the effectiveness of measurements can be calculated. Saaty (1987) proposed the maximum eigenvalue γ_{max} b: $\gamma_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}, i = 1, \ldots, n$. With the maximal eigenvalue γ_{max}, a Consistency Index (CI) can then be determined by: $CI = \frac{\gamma_{max} - n}{n-1}$ then a Consistency Ratio (CR) is defined by: $CR = \frac{CI}{RI}$. Table 3 shows the average amount of Random Index (RI) with the value obtained by different orders of the pair-wise comparison matrices. If the CR has a value below 0.1 then the matrix is considered consistent, the evaluation is rational and the weights are valid. In the case of CR>0.10, the judgments should be reviewed and improved.

TOPSIS can be used the obtained weighs to compute the ranking. TOPSIS calculates geometric distance of the alternatives from their positive ideal solution and negative ideal solution and chose the best alternative based on the shortest distance from the positive ideal solution and longest distance from the negative ideal solution. After criteria selection and weights extraction, decision matrix can be shown as ($D = [x_{ij}]_{mn}$) in which rows ($i = 1, , m$) show alternatives and columns ($j = 1, , n$) show criteria and each alternative give a score in each criterion named by x_{ij}. TOPSIS uses vector normalization by Eq. 2 (Hwang and Yoon, 1981).

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \forall i = 1, , m \ \text{ and } \ \forall j = 1, , n \qquad (2)$$

By multiplying each normalized value R_{ij} to its corresponding weight W_j to calculate weighted normalized matrix is obtained by Eq. 3 (Hwang and Yoon, 1981).

$$V_{ij} = W_j R_{ij} \qquad (3)$$

The positive ideal solution, maximum value of alternatives in each attribute, ($V^+ = V_1^+, V_2^+, \ldots, V_n^+$) and the negative ideal solution, minimum value of alternatives in each attribute ($V^- = V_1^-, V_2^-, \ldots, V_n^-$)

can be constructed. The separation measure can be calculated by Eq. 4 and Eq. 5 (Hwang and Yoon, 1981).

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^*\right)^2} \quad \forall i = 1,,,n \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2} \quad \forall i = 1,,,n \tag{5}$$

The relative closeness to the ideal solution is calculated by Eq. 6 (Hwang and Yoon, 1981).

$$C_i^+ = \frac{S_i^-}{S_i^+ + S_i^-} \quad \forall i = 1,,,n \tag{6}$$

The final ranking is achieved and can be used for future actions. According to the DMAIC methodology, the obtained results should be analyzed and improvement strategies should be conducted and implemented. Then the implementations should be controlled. The designed action plan should be implemented and monitored. If the implementation is not according to the plan, some corrective actions will be defined and implemented to reach the improvement goals.

RESULTS AND DISCUSSION

The fact that DMAIC is a well-known methodology, can help Tehran Municipality to make a better situation for the citizens. So, the proposed method is applied in Tehran Municipality. Tehran City is divided into 22 districts. Tehran Municipality has got 8 deputies who monitor the performance of the districts. Human capital development, project control, budgeting, and coordination of the municipality with the city council are done by the deputy of planning, human capital development, performance monitoring and assessment, and council affairs. Identifying and collecting income and economic issues are related to the deputy of finance and urban economics. All the districts should be coordinated by the Tehran Municipality and have proper performance so, the deputy of coordination and affairs monitor the coordination. City construction and technical planning are done by the deputy of Technical and construction. Public transportation and traffic safety issues are related to the deputy of Traffic transportation. Women's affairs, citizenship training, general directorate of health, general directorate of urban planning and development, and social and cultural developments are done by the deputy of social and cultural affairs. The deputy of urban services and environment has the following duties: general directorate of urban and development of urban services affairs and development of environment and general direction of municipal services. The general directorate of privacy, general directorate of regulations, supervision and licensing, general directorate of architecture and building, secure historical monuments of Tehran, and development of urban planning and architecture affairs are done by the deputy of urban planning and architecture. The performance of the districts should be monitored and improved to obtain sustainable improvement. DMAIC methodology that is elevated by BSC, AHP, TOPSIS, and clustering algorithms is applied to Tehran Municipality. Six sigma experts of each deputy are gathered together to define proper measures and design the BSC of Tehran Municipality. Outcome measures (lagging indicators) as objectives and performance drivers (leading indicators) as sub–measures of these outcomes are the essential points that should be considered in a proper BSC. Performance drivers and outcome measures help organizations implement selected strategies, improve operations, obtain financial goals, and achieve proper outcomes. KPIs are the performance drivers that are used to measure the level of achievement of the outcome measures (objectives). The proposed BSC is composed of 4 separate, 3 hierarchy levels. Each level represents an important perspective of a Tehran Municipality and inside the perspective, related goals and measures of the perspective are presented. The 4 perspectives are as follows:

- Learning and growth,
- Internal processes,
- Urban development,
- Financial

Each perspective has a strategic goal and some objectives. Each objective can be calculated by some KPIs. So, as a hierarchical performance assessment system, top-level or level one is considered strategic goals, level two has consisted of outcomes as objectives, and the third level is composed of performance drivers as KPIs. Therefore as a hierarchical performance assessment system (Goal,

Table 4: BCS for Tehran Municipality

Perception	Strategic goal		Objective goals	
Financial	Reaching financial growth	KPI	Increase Municipality income Increase productivity Increase municipal incomes Entrepreneurship	Reduce cost Reduce operational costs Control wages Minimize usage cost of public facilities
Urban development	Develop city's structures and infrastructures	KPI	Increase clean transportation Decrease price of bicycle Increase green public transportation Upgrade transportation equipment	Increase city resilience create and maintain safeguards for citizens Social stability Minimal vulnerability of citizens
Internal processes	Achieving matured processes	KPI	Strengthening internal control Promote state supervision Drawing process flow charts Drawing organization functional charts	Reaching an excellent level of operation Upgrade internal equipment's Level of Funds Employed Staff training
Learning and growth	Increase efficiency of employees	KPI	Increase knowledge of employees Access to Information/Knowledge Increase workshops Increase seminars Increase educational classes	Increase motivation of employees Moral Award Prize money Self-Motivation Evaluation

objectives, KPIs) at first, four separate perspectives are defined with the help of BSC and then are customized for Tehran Municipality. Then strategic goal of each perspective is defined, some related outcomes as objectives for each perspective are defined and in the next step, performance measures for the defined objects are defined.

Perspective: Learning and growth

• Strategic goal: Increase efficiency of employees

• Objective goals:

• Increase knowledge of employees

• Increase the motivation of employees

Perspective: Internal processes

• Strategic goal: Achieving matured processes

• Objective goals:

• Strengthening internal control

• Reaching an excellent level of operation

Perspective: Urban development

• Strategic goal: Develop city's structures and infrastructures

• Objective goals:

• Increase clean transportation

• Increase city resilience

Perspective: Financial

• Strategic goal: Reaching financial growth

• Objective goals:

• Increase Municipality income

• Reduce cost

Table 4 shows the BCS for Tehran Municipality.

AHP is used to calculate the weights of elements on BSC for each distinct and TOPSIS is applied to compute the rank and score of each distinct in each element. Concerning security issues, no real data has been used. Tables 5 and 6 show the weight, score, and rank for an imaginary district by arbitrary data and Table 7 shows the final ranking.

Discussion

If managers can divide their activities based on different KPIs into different groups, they might be able to improve the situation of the organization efficiently. For this purpose, clustering techniques are the most appropriate methods. They can help managers to better understand their current situations, strengths, and weaknesses and conduct the right strategies for each group to attain sustainable improvement. Wards and K-mean algorithms, as two prominent clustering algorithms, with the help of Statistical Package for the Social Sciences (SPSS) are used here for cluster analysis. The number of clusters is equal to 5. Inferior (I), Somewhat Inferior (SI), Moderate (M), Somewhat Superior (SS) and Superior (S) are the names of the clusters. Each district can be put on a cluster based on its performance score. Table 8 shows the results.

Clustering algorithms try to minimize within-group variances and maximize between-group

Table 5: Weights of indexes for a district

Perception	Weights		Objective goals	Weights	Objective goals	Weights
Financial	25 percent (%)	KPI	Increase Municipality income	70%	Reduce cost	30%
			Increase productivity	20%	Reduce operational costs	30%
			Increase municipal incomes	40%	Control wages	50%
			Entrepreneurship	40%	Minimize usage cost of public facilities	20%
Urban development	20%	KPI	Increase clean transportation	20%	Increase city resilience	80%
			Decrease price of bicycle	15%	create and maintain safeguards for citizens	25%
			Increase green public transportation	35%	Social stability	45%
			Upgrade transportation equipment	50%	Minimal vulnerability of citizens	30%
Internal processes	35%	KPI	Strengthening internal control	45%	Reaching an excellent level of operation	55%
			Promote state supervision	10%	Upgrade internal equipment's	10%
			Drawing process flow charts	40%	Level of Funds Employed	45%
			Drawing organization functional charts	50%	Staff training	45%
Learning and growth	20%	KPI	Increase knowledge of employees	40%	Increase motivation of employees	60%
			Access to Information/Knowledge	60%	Moral Award	5%
			Increase workshops	20%	Prize money	20%
			Increase seminars	10%	Self-Motivation	45%
			Increase educational classes	10%	Evaluation	30%

Table 6: Performance and rank for a district

Perception	Rank (score)	Objective goals	Rank (score)	Objective goals	Rank (score)
Financial	15 (35%)	Increase Municipality income	12 (50%)	Reduce cost	17 (41%)
		Increase productivity	15 (30%)	Reduce operational costs	18 (25%)
		Increase municipal incomes	18 (19%)	Control wages	20 (19%)
		Entrepreneurship	17 (35%)	Minimize usage cost of public facilities	12 (52%)
Urban development	10 (50%)	Increase clean transportation	9 (55%)	Increase city resilience	12 (50%)
		Decrease the price of bicycle	8 (50%)	Create and maintain safeguards for citizens	15 (32%)
		Increase green public transportation	5 (75%)	Social stability	10 (57%)
		Upgrade transportation equipment	10 (59%)	Minimal vulnerability of citizens	3 (85%)
Internal processes	3 (85%)	Strengthening internal control	1 (90%)	Reaching an excellent level of operation	5 (70%)
		Promote state supervision	1 (75%)	Upgrade internal equipment	1 (87%)
		Drawing process flow charts	5 (79%)	Level of Funds Employed	2 (85%)
		Drawing organization functional charts	3 (89%)	Staff training	7 (50%)
Learning and growth	22 (5%)	Increase knowledge of employees	21 (8%)	Increase the motivation of employees	22 (4%)
		Access to Information/Knowledge	15 (25%)	Moral Award	22 (3%)
		Increase workshops	18 (30%)	Prize money	21 (7%)
		Increase seminars	19 (4%)	Self-Motivation	19 (12%)
		Increase educational classes	20 (7%)	Evaluation	18 (5%)

variances. Finding clusters with meaningful groups embedded is a critical issue in clustering algorithms. Now, a criterion is needed to choose the proper and meaningful clustering algorithm. An expert's idea is used here. Concerning Table 8, the expert's perceptions of the performance of the districts are not

Table 7: Final rank of the districts

District	Score	Rank
District 9	89.75%	1
District 16	76.36%	2
District 8	74.52%	3
District 13	69.45%	4
District 7	63.09%	5
District 17	53.04%	6
District 14	53.04%	7
District 4	51.62%	8
District 20	51.38%	9
District 6	51.02%	10
District 5	50.92%	11
District 3	50.19%	12
District 21	46.85%	13
District 15	46.26%	14
District 2	43.73%	15
District 19	43.63%	16
District 11	41.57%	17
District 12	36.92%	18
District 10	34.19%	19
District 22	30.43%	20
District 1	14.15%	21
District 18	10.12%	22

aligned with the results of the clustering algorithms. So, they might want another clustering of the data. Six Sigma defines upper and lower control limits that might be used as a clustering algorithm. Here, those limits are adopted to define some clusters as follows:

Imaging is μ the average of the final scores and σ is their standard deviation. By applying Six Sigma as a clustering algorithm following clusters are proposed: If the performance of a district is between [$\mu-\sigma$, $\mu+\sigma$) so, it has the same performance in comparison with other districts. If the performance of a district is between [$\mu+\sigma$, $\mu+2\sigma$) so, it has a somewhat superior performance in comparison with other districts. If the performance of a district is between [$\mu+3\sigma$, $+\infty$) so, it has a superior performance in comparison with other districts. If the performance of a district is between [$\mu-2\sigma$, $\mu-\sigma$) so, it has a somewhat inferior performance in comparison with other districts. If the performance of a district is between ($-\infty$, $\mu-2\sigma$) so, it has inferior performance in comparison with other districts. By applying the six-sigma clustering method to the final scores of districts, 3 clusters are composed. Therefore, the K-mean and Wards algorithm by 3 clusters is applied to the data. Table 9 shows the comparison of the results. According to the table, district 7 puts on a Moderate cluster by the Six Sigma algorithm, but it puts on a Somewhat Superior cluster by K-mean and Wards. Also, district 22 puts on the Somewhat Inferior cluster by the Six Sigma algorithm, but it puts on the Inferior cluster by K-mean and Wards.

According to the expert's idea, achieved clusters

Table 8: K-man and Wards clustering (5 clusters)

District	score	K-mean (5 clusters)	Wards (5 clusters)
District 9	0.8975	S	S
District 16	0.7636	SS	S
District 8	0.7452	SS	S
District 13	0.6945	SS	S
District 7	0.6309	SS	S
District 17	0.5304	M	SS
District 14	0.5304	M	SS
District 4	0.5162	M	SS
District 20	0.5138	M	SS
District 6	0.5102	M	M
District 5	0.5092	M	M
District 3	0.5019	M	M
District 21	0.4685	M	SI
District 15	0.4626	M	SI
District 2	0.4373	SI	SI
District 19	0.4363	SI	SI
District 11	0.4157	SI	SI
District 12	0.3692	SI	SI
District 10	0.3419	SI	SI
District 22	0.3043	SI	SI
District 1	0.1415	I	I
District 18	0.1012	I	I

by six sigma limits were accepted for the improvement phase. By regarding the weighted standard score of the indexes of each district, improvement priority can be obtained. Then, the roots of the low score should be found to be used in the improvement phase. All the districts are sorted according to their final TOPSIS score and the following thresholds are used to classify their performance: According to the thresholds, no district has the superior performance. 4 districts have somehow superior performance. 15 districts put on moderate performance cluster. 3 districts have somehow inferior performance. Roots of the low score of each district in the perspectives, goals, and indexes should be found. Then an action plan for each district should be defined. For instance, imagine that district one has got a low mark in staff training, therefor probably some high-quality courses should be defined and executed for the staff to promote their capability to reach to excellent level of operation. As another example, imagine district two has got a very low mark in clean transportation goal and the main reason for the score is the price of bicycles, therefore the mayor should find a way to solve the problem maybe by renting bicycles to the citizens or distributing some low-price bicycles. It is worth noting that cost and benefit analysis should be done in this step and some improvement projects that are not feasible should be omitted. A lot of corrective actions have been defined in the improvement phase. So, the actions should be done and controlled to make progress and improvement for the city. Some new indexes or goals can be defined here to control the improvement of the district. The owner of each corrective action by the related duration, start and

Table 9: Six sigma, K-man, and Wards clustering (3 clusters)

District	score	Sig Sigma	K-mean (3cluster)	Wards (3 cluster)
District 9	0.8975	SS	SS	SS
District 16	0.7636	SS	SS	SS
District 8	0.7452	SS	SS	SS
District 13	0.6945	SS	SS	SS
District 7	0.6309	M	SS	SS
District 17	0.5304	M	M	M
District 14	0.5304	M	M	M
District 4	0.5162	M	M	M
District 20	0.5138	M	M	M
District 6	0.5102	M	M	M
District 5	0.5092	M	M	M
District 3	0.5019	M	M	M
District 21	0.4685	M	M	M
District 15	0.4626	M	M	M
District 2	0.4373	M	M	M
District 19	0.4363	M	M	M
District 11	0.4157	M	M	M
District 12	0.3692	M	M	M
District 10	0.3419	M	M	M
District 22	0.3043	SI	M	M
District 1	0.1415	SI	SI	SI
District 18	0.1012	SI	SI	SI

finish time and proper budget should be clarified. On the other hand, Choosing the right MCDM technique is a vital decision in ranking and improvement strategy making. TOPSIS is one of the most prevalent technique in MCDM. TOPSIS use vector normalization to normalize the scores. Linear scale transformation (sum), linear scale transformation (max), linear scale transformation (max-min), and also standardization to standardize the data are other ways that can be used to normalize the data and rank the distinct. Linear scale transformation (sum) use $a_{ij}=\frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$ to normalize the data, linear scale transformation (max) as: $a_{ij}=\frac{x_{ij}}{x_j^{max}}$ for benefit attribute and $a_{ij}=1-\frac{x_{ij}}{x_j^{max}}$ for cost attribute as x_j^{max} is the maximum performance rating among alternatives for the jth attribute; linear scale transformation (max-min) as $a_{ij}=\frac{x_{ij}-x_j^{min}}{x_j^{max}-x_j^{min}}$ for benefit attribute and $a_{ij}=\frac{x_j^{max}-x_{ij}}{x_j^{max}-x_j^{min}}$ for cost attribute as x_j^{min} is the minimum performance rating among alternatives for the jth attribute, standardization use mean (μ) and standard division (σ) of data by the following formula $a_{ij}=\frac{x_{ij}-\mu}{\delta}$ to make the data dimensionless and comparable. Simple Weighted Method (SWM) is another well-known MCDM technique. SWM calulates the score of each alternative by the following formula $fo\ all\ i=1,,,m$ by $A_{i-score}=\sum_{j=1}^{n} W_j a_{ij}$ and ranks the alternatives according to the heights score. This section compares TOPSIS and SWM ranking to find out the best technique for an imaginary problem. Table 10 presents imaginary data for the district in four aspects.

Tables 11 and 12 present the results of SWM and TOPSIS techniques by different normalization and standardization methods.

10 different solutions now are available and the main question here arises which one should be

Table 10: Imaginary data for the district in four aspects

Aspects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Financial	48	25	12	87	46	55	4	24	12	96	21	42	90	97	40	34	46	47	58	18	23	22
Urban development	17	37	10	25	22	22	28	52	65	27	28	60	51	98	55	61	66	36	87	51	54	90
Internal processes	57	53	99	32	95	99	89	53	57	66	70	55	82	19	48	46	19	19	10	7	24	8
Learning and growth	67	13	62	62	7	14	2	69	61	19	79	61	63	78	31	81	39	86	47	76	80	64

Table 11: Results of TOPSIS technique by different normalization and standardization methods

	Vector Normalization		Standardization $a_{ij} = \frac{x_{ij} - \mu}{\delta}$		Linear Scale Transformation (Sum) $a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$		linear Scale Transformation (Max)as: $a_{ij} = \frac{x_{ij}}{x_j^{max}}$		Linear Scale Transformation (Max-Min) as: $a_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}$	
Districts	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	0.27	10	0.47	9	0.47	8	0.49	7	0.48	7
2	0.08	21	0.23	21	0.23	20	0.22	21	0.22	21
3	0.16	20	0.26	20	0.23	21	0.28	20	0.27	20
4	0.64	4	0.70	3	0.74	3	0.73	3	0.72	3
5	0.21	16	0.37	16	0.39	13	0.37	17	0.37	16
6	0.28	7	0.44	11	0.47	7	0.44	11	0.44	11
7	0.07	22	0.09	22	0.09	22	0.09	22	0.09	22
8	0.20	17	0.37	15	0.33	16	0.38	15	0.38	15
9	0.19	18	0.32	19	0.27	19	0.32	19	0.32	19
10	0.67	3	0.66	4	0.71	4	0.66	4	0.66	4
11	0.22	14	0.35	18	0.31	17	0.37	16	0.36	17
12	0.25	12	0.48	7	0.46	10	0.48	8	0.48	8
13	0.71	2	0.79	2	0.81	2	0.80	2	0.79	2
14	0.91	1	0.93	1	0.93	1	0.92	1	0.92	1
15	0.19	19	0.40	13	0.40	12	0.39	14	0.40	14
16	0.28	9	0.46	10	0.43	11	0.47	9	0.47	10
17	0.25	11	0.47	8	0.47	9	0.47	10	0.47	9
18	0.33	6	0.52	6	0.50	6	0.54	6	0.53	6
19	0.41	5	0.60	5	0.60	5	0.59	5	0.60	5
20	0.22	15	0.35	17	0.31	18	0.36	18	0.36	18
21	0.25	13	0.39	14	0.35	15	0.40	12	0.40	13
22	0.28	8	0.41	12	0.36	14	0.40	13	0.40	12

considered the best one? One answer can be reached by calculating the sum of the absolute difference between the rank of the district in each technique by the others. According to Table 13 Linear Scale Transformation (Sum) is the most robust solution for the mentioned example.

It is worth answering the mentioned questions here: How DMAIC methodology can be applied in an organization as a performance management tool? Defining Tehran Municipality is done based on its deputies. In this way, all the activities, inputs, processes, outputs, and outcomes are defined by each deputy. Then a hierarchical performance assessment system (Goal, objectives, KPIs) is applied for a more accurate definition of the problem. AHP and TOPSIS are used in the measurement phase to calculate the

Table 12: Results of SWM technique by different normalization and standardization methods

	Vector Normalization		Standardization $a_{ij} = \frac{x_{ij} - \mu}{\delta}$		Linear Scale Transformation (Sum) $a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$		linear Scale Transformation (Max)as: $a_{ij} = \frac{x_{ij}}{x_j^{max}}$		Linear Scale Transformation (Max-Min) as: $a_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}$	
Districts	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	9.70	10	-0.02	11	0.05	10	0.51	9	0.47	9
2	3.07	21	-0.79	21	0.03	21	0.27	21	0.23	21
3	5.65	20	-0.71	20	0.03	20	0.31	20	0.27	20
4	19.99	4	0.67	3	0.07	3	0.70	3	0.67	3
5	6.50	19	-0.52	19	0.03	19	0.35	19	0.32	19
6	8.68	13	-0.28	16	0.04	13	0.42	17	0.39	17
7	2.11	22	-1.29	22	0.01	22	0.13	22	0.09	22
8	8.20	14	-0.15	13	0.04	15	0.46	13	0.43	13
9	7.65	17	-0.33	18	0.03	18	0.40	18	0.37	18
10	20.97	3	0.50	4	0.06	4	0.64	4	0.62	4
11	8.09	15	-0.28	17	0.04	16	0.43	15	0.40	15
12	10.50	9	0.17	8	0.05	7	0.54	8	0.52	8
13	23.84	2	1.04	2	0.07	2	0.79	2	0.78	2
14	32.95	1	1.60	1	0.09	1	0.94	1	0.93	1
15	7.06	18	-0.20	14	0.04	14	0.43	14	0.40	14
16	11.73	7	0.21	7	0.05	8	0.56	7	0.53	7
17	9.36	11	0.03	9	0.05	9	0.49	10	0.47	10
18	12.41	6	0.24	6	0.05	6	0.58	6	0.55	6
19	15.13	5	0.48	5	0.06	5	0.62	5	0.60	5
20	8.00	16	-0.28	15	0.04	17	0.42	16	0.39	16
21	9.34	12	-0.10	12	0.04	12	0.47	12	0.44	12
22	11.24	8	0.01	10	0.04	11	0.49	11	0.46	11

Table 13: Sum of the absolute difference between the ranks of the district in each technique by the others

Technique	Method	Sum of absolute differences
TOPSIS	Vector Normalization	312
	Standardization	208
	Linear Scale Transformation (Sum)	312
	linear Scale Transformation (Max)as	184
	Linear Scale Transformation (Max-Min)	188
SWM	Vector Normalization	238
	Standardization	202
	Linear Scale Transformation (Sum)	168
	linear Scale Transformation (Max)as	188
	Linear Scale Transformation (Max-Min)	188

weights of the elements and the scores of the districts. K-mean, wards, and Six Sigma control limits are used for analyzing phase. The improvement phase is done by finding the roots of weaknesses in the previous step. Once the implementation of enhancement strategies has been completed, it is crucial to proceed with the control step. To effectively cluster the data, the utilization of six-sigma control limits can prove to be highly beneficial. The discussion section provides a comprehensive answer to how these control limits

can be employed for this purpose. The application of MCDM techniques within the DMAIC methodology involves utilizing AHP for determining the weights of various elements, followed by the implementation of TOPSIS to rank the different districts based on the established criteria. The application of the Balanced Scorecard (BSC) within the DMAIC methodology can be explored by considering its implementation in the define phase, specifically concerning the hierarchical performance assessment system. This system encompasses the establishment of goals, objectives, and key performance indicators (KPIs). By incorporating the BSC, a different approach can be taken to enhance the effectiveness of this assessment system, allowing for a more comprehensive evaluation of performance within the DMAIC framework. The DMAIC methodology can be enhanced by integrating the BSC, MCDM, and clustering algorithm to introduce a more intricate approach. In the defining phase, the BSC is utilized to establish a clear framework. During the measurement phase, AHP and TOPIS are employed to gather relevant data. Finally, in the analysis phase, clustering algorithms are applied to analyze the collected information and identify patterns or groups. By combining these different techniques, the DMAIC methodology can provide a comprehensive and robust solution to complex problems.

CONCLUSION

This study showed how DMAIC methodology as a reputable methodology of Six Sigma can be applied in Tehran Municipality. The methodology has been elevated by BSC, TOPSIS, AHP, and clustering algorithms. 1) The define phase is based on BSC and is done at 3 hierarchy levels. Learning and growth, Internal processes, Urban development, and Financial are four defined perspectives. Each perspective has a strategic goal, and some objectives, and each object can be calculated by some key performance indicators. 3) The measure phase is done by AHP and TOPSIS. Weights of the elements of BSC are calculated based on AHP and district ranking is done by TOPSIS. 2) Wards and K-mean algorithms as two prominent clustering algorithms are used in the analysis phase. Moreover, by applying Six Sigma as a clustering algorithm following clusters are proposed: The performance tolerances are defined based on the standard deviation of data. If the performance of a district is between $[\mu-\sigma, \mu+\sigma)$ so, it has the same performance in comparison with other districts. If the performance of a district is between $[\mu+\sigma, \mu+2\sigma)$ so, it has a somewhat superior performance in comparison with other districts. If the performance of a district is between $[\mu+3\sigma, +\infty)$ so, it has a superior performance in comparison with other districts. If the performance of a district is between $[\mu-2\sigma, \mu-\sigma)$ so, it has a somewhat inferior performance in comparison with other districts. If the performance of a district is between $-\infty, \mu-2\sigma)$, it has inferior performance in comparison with other districts. 4) The improvement phase traces back to the BSC levels and finds out the strengths and weaknesses of the districts based on the weights and performance and defines improvement plans. 5) The control phase tries to control the execution of improvement plans. Moreover, 4 different normalization ways linear scale transformation (sum), linear scale transformation (max), linear scale transformation (max-min), vector normalization, and also standardization to standardize the data, and TOPSIS and SWM techniques are used to normalize the data and rank the distinct. In this way, 10 different solutions are obtained and a criterion is proposed to select the most suitable solution. For further research, providing statistical analysis can be used to test the stability of the clusters and group the scores into meaningful clusters.

AUTHOR CONTRIBUTIONS

K. Fahimi performed the literature review, conducted the conceptual model, and numerical results, compiled the data, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. M. Amirabadi performed the literature review and applied the model in Tehran Municipality.

ACKNOWLEDGMENT

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors are very grateful to all the experts who cooperated in providing the data.

CONFLICT OF INTEREST

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

ABBREVIATIONS

%	Percent
AHP	Analytical Hierarchical Process
ANOVA	Analysis of variance
BSC	Balanced Score Card
CI	Consistency Index
CR	Consistency Ratio
FTOPSIS	Fuzzy Technique for Order of Preference by Similarity to Ideal solution
FAHP	Fuzzy analytical hierarchical process
MBNQA	Malcolm Baldrige National Quality Award
MCDM	Multi-Criteria Decision-Making
RI	Random Index
SPSS	Statistical Package for the Social Sciences
SWM	Sample Weighted Method
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TQM	Total Quality Management
$A=\left[a_{ij}\right]$	Pairwise comparison matrix.
a_{ij}	Amount of preference of element i to element j.
$\left(W_1,..,W_n\right)$	Vector of weights.
C	An n-dimensional column vector.
$CV=\left[cv_i\right]_{1*n}$	Consistency value.
γ_{max}	Maximum eigenvalue.
CI	Consistency index.
RI	Average random index.
$D=\left[x_{ij}\right]_{mn}$	Decision matrix.
x_{ij}	Score of alternatives i in criteria j.
R_{ij}	Normalized amount of x_{ij}.
V_{ij}	Weighted normalized amount of x_{ij}.
$(V^+=V_1^+,V_2^+,\ldots,V_n^+)$	The maximum value of alternatives in each attribute.
$(V^-=V_1^-,V_2^-,\ldots,V_n^-)$	The minimum value of alternatives in each attribute.
S_i^+	Positive separation measure.
S_i^-	Negative separation measure.
C_i^+	Relative closeness to the ideal solution.
μ	Average of the final scores.
σ	Standard deviation of the final scores.

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HOW TO CITE THIS ARTICLE

Fahimi, K.; Amirabadi, M., (2024). Applying Six Sigma methodology to improve performance in organizations. Int. J. Hum. Capital Urban Manage., 9(3): 537-552.

DOI: 10.22034/IJHCUM.2024.03.12

URL: https://www.ijhcum.net/article_712212.html

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Volume 9, Number 3, Summer 2024
(Serial # 35)