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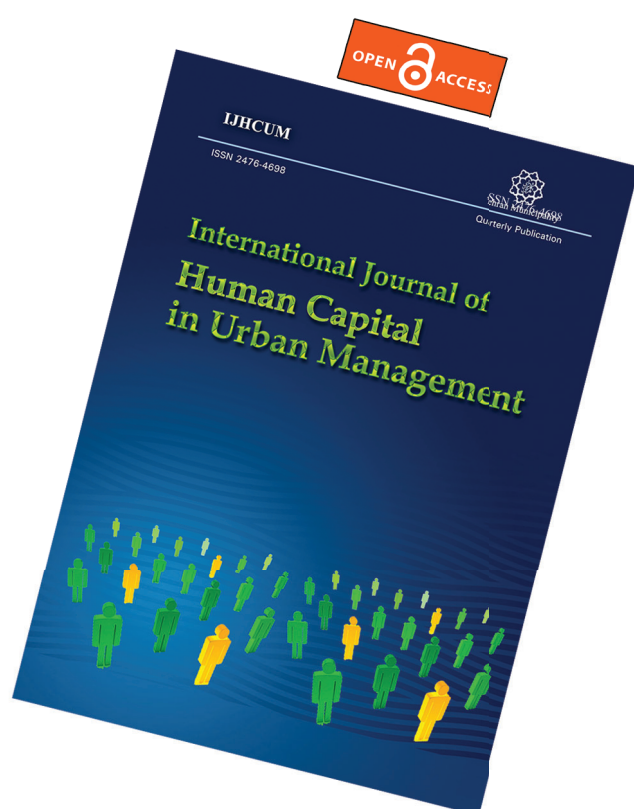
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CONTENTS

Volume 10, Number 1, Winter (2025)

1	Reverse osmosis for the treatment of well water and wastewater for reuse A. Melendez-Rivera, J.C. Musa-Wasil, D.K. Almestica-Martinez, K.J. Malave-Llamas, (USA)	1
2	On the master plan conformance with urban reality: A comparative assessment M. Jahanbani, E. Lashkari, (CANADA/IRAN)	23
3	Structural equation modeling of collective decision-making's impact on group cohesion S.M. Mirbagheri, A. Rafiei Atani, M.R. Parsanejad, R. Jafari, (IRAN)	39
4	Integrating human resource management in urban workforce development: A focus on salary increments L. Yu, A.R. Santos, (CHINA/PHILIPPINES)	57
5	Exploring individual and organizational contributors to workplace deviant behavior D. Daryono, R.S. Gunawan, U. Udin, (INDONESIA)	71
6	On the concept of Urban Mutations: Urban research bibliography with an objective approach Z. Bendebache ; A. Khiari; I. Maanser, (ALGERIA)	85
7	The influence of pandemics in neighborhoods' public realms: Experts' point of view in light of social capital A. Asadpour, H. Nikounam Nezami, (IRAN)	105
8	Statistical analysis based on a two-staged SEM-SVM approach for environmental noise annoyance prediction and identification of influencing factors M.U. Rehman, M. Kamal, S.K. Tiwari, (SAUDI ARABIA/INDIA)	121
9	A closer look at the work behavior of Gen Z in Micro, Small, and Medium Enterprises of developing countries I. Astuty, R. J. Astuti, S. M. Mahmud, V. Widodo, (INDONESIA)	135
10	The mediating effect of job satisfaction in the relationship between wages, appreciation, recognition, and promotion on employee performance D. Kumar, H. Vasudevan, (IRAN)	149
11	Effect of technology application in enhancing the weaknesses of market access, financial resources, and supplier resources on the aluminum industry M.S. Mohamad Salleh, H. Vasudevan, (MALYSIA)	163
12	Bibliometric analysis of research trends in Green Human Resource Management and sustainable development S.Pooja, J.Bhavani, (INDIA)	179

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ORIGINAL RESEARCH PAPER

Reverse osmosis for the treatment of well water and wastewater for reuse

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ABSTRACT

BACKGROUND AND OBJECTIVES: Freshwater is a scarce resource, constituting only 2.5% of Earth's total water. Approximately 90% of freshwater is concentrated near the South Pole of the Antarctic Circle, exacerbating its scarcity for living organisms. Industries such as pharmaceuticals, textiles, food production, and agriculture rely heavily on monthly freshwater supplies for their operations. Proper disposal of wastewater from these sectors is imperative to meet environmental standards. This study aimed to evaluate the effectiveness of reverse osmosis systems in treating well water for human consumption, examine the possibility of reusing reverse osmosis treated wastewater, and assess the feasibility of reducing freshwater consumption and wastewater generation.

METHODS: The study used the qualitative and quantitative data obtained in 2018, 2019, 2022, and 2023 from the manufacturing industry in Guayama, Puerto Rico. Statistical analysis was confidently conducted using the Paired T-Test and Pearson correlation tests, with Minitab Statistical Software (Version 21.1.0) utilized for statistical analysis.

FINDINGS: The results of this study showed that reverse osmosis is an effective system for treating well water for human use and enabling the reuse of wastewater after treatment. A total of 2,397,000 gallons of wastewater were treated and reused for cooling towers and boilers, representing the same amount of freshwater conserved and wastewater not discharged into the sewer system. The metrics analyzed were total organic carbon, conductivity, nitrate levels, and total aerobic microbial population. Total organic carbon in the samples ranged from 3 to 29 ppb. Conductivity was between 0.3 $\mu\text{S}/\text{CM}$ and 1.0 $\mu\text{S}/\text{CM}$. Nitrate levels were all under 0.2 ppm (0.2 mg/l). Total aerobic bacteria counts were 0 cfu per milliliter. Regarding the feasibility of reusing wastewater post-reverse osmosis treatment, the findings showed decreased levels of anions and cations in the treated wastewater. Additionally, all reverse osmosis-treated well water samples tested in 2022 met the quality control laboratory criteria.

CONCLUSION: The study confirms that the reverse osmosis system effectively purifies well water for human use and demonstrates the potential for repurposing treated wastewater. Furthermore, 2,397,000 gallons of treated wastewater were repurposed for cooling towers and boilers, conserving freshwater resources, and preventing the discharge of an equivalent volume of wastewater into the sewer system.

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INTRODUCTION

Fresh water is a non-renewable natural resource that only represents 2.5% of the total water on the planet Earth. Approximately 90% of the freshwater resources available on the planet are in the South Pole of the Antarctic Circle, which makes the amount of freshwater available for living beings even more limited (Australian Antarctic Program, 2020). Currently, there is a global crisis related to the insufficient supply of this resource which is influenced by the growing demand for water to satisfy human, industrial, and/or agricultural needs. The industrial sector uses about 20% of the extracted water (freshwater) worldwide to carry out its processes and it is expected that by 2025, this percentage will increase to approximately 24% (United Nations, 2011). Regarding the agricultural sector, it uses approximately 70% of the freshwater extracted in the world (World Bank, 2022). The United Nations reports estimate that water scarcity affects more than 40% of the world's population and expects this percentage to increase if current water use continues (United Nations, 2020). The current large amounts of freshwater use and the consequences of continuing with current use make evident the need to implement measures for all lives to minimize the use of freshwater and its overexploitation. Currently, different countries in the world have great difficulties accessing drinking water services. According to the United Nations, approximately 750 million people around the world lack adequate access to water. They also estimated that this number will increase to 2.9 billion people by 2030, which represents around a third of the world's population (United Nations, 2023). This situation will increase diseases caused by the consumption of contaminated water. An example of a country that has a high percentage of homes that lack drinking water services is Peru. According to the last census carried out in Peru, 67.5% of homes have drinking water service while 32.5% do not have this service. It is important to mention that more than 80% of wastewater worldwide is returned to the environment without being treated. The industrial sector generates large quantities of wastewater monthly and is also one of the largest contributors to water pollution since it annually dumps between 300 and 500 million tons of wastewater, which contains solvents, heavy metals, or other polluting waste. In developing countries, about 70% of industrial wastewater is

discharged into waters without any treatment (United Nations, 2011). This waste causes drinking water to become non-drinkable which in turn causes the death of fish. Unfortunately, around 800 thousand deaths a year are caused because of drinking contaminated water (Solís, 2017). Many manufacturing industries operate in Puerto Rico (Pharmaceutical industries, textile industries, and food industries among many others) which need large quantities of fresh water monthly to carry out their processes. In addition, the agricultural sector on the island is another sector that depends on large amounts of fresh water to grow fruits, and vegetables and raise livestock. In the past, these sectors have faced problems due to water shortages, mainly during times of drought. In 2015, approximately 38.5 inches of rain fell, compared to 45 inches from 1994 to 1997. During the 2015 drought, the agricultural sector lost approximately \$12 million, prompting the Federal Department of Agriculture to declare the area a natural disaster on July 15, 2015. Losses were caused by heat stress from high temperatures and soil desiccation due to a lack of water. This resulted in lower crop yields and higher livestock mortality (Hub, 2016). In Puerto Rico, it is estimated that 228 million gallons of wastewater are treated per day and that the majority of this is discharged into the ocean and rivers. This significant amount of water could be reused in places such as agricultural irrigation and industrial processes, among others. In 2010, approximately 724 million gallons per day (mgd) were extracted in Puerto Rico from different freshwater sources around the island. Of these, 38.2 mgd were used for crop irrigation (Quiñones, 2015). According to the Department of Natural and Environmental Resources, by 2030 it is estimated that the agricultural sector will use around 84.2 mgd of water for irrigation systems (Department of Natural and Environmental Resources, 2015). It is important to mention that in Puerto Rico water quality is controlled through the Puerto Rico Water Quality Standards Regulation. This regulation seeks to mitigate degradation and protect coastal, surface, and groundwater. According to the November 2018 303(d) Impaired Water List from the United States Environmental Protection Agency, there are 666 cases of contaminants that are causing water deterioration across the island. These cases are associated with surface water, groundwater, and reservoirs. Of the mentioned contaminant cases, around 12,090 miles

were in rivers, streams, and creeks in the 2018 year, the main sources of pollutants reported in Puerto Rico were wastewater discharges ([Environmental Protection Agency \[EPA\], 2020](#)). Flora, fauna, and fish need to have sufficient water flow through the habitats in which they live and reproduce. If water flow is not adequate due to the diversion of water for urban, industrial, and agricultural purposes, the quality of water and the health of ecosystems will deteriorate ([Quiñones and Guerrero, 2004](#)). The use of reverse osmosis for the treatment of wastewater and its reuse allows for maintaining the flow of water by not having to divert large quantities of water. Reusing wastewater after being treated by reverse osmosis also reduces its discharge to bodies of water such as oceans, estuaries, and rivers. In addition, the habitat of different species is protected and the contamination of different bodies of water is reduced and prevented. Treating wastewater and reusing it in tasks such as irrigation increases the nutrients available for agriculture and reduces the need to use synthetic fertilizers ([Quiñones and Guerrero, 2004](#)). Although in Puerto Rico there is currently enough fresh water to satisfy the needs of its population of about 3.2 million people, it can be seen how it is becoming more common every day in other countries that its distribution is unequal, contaminated, and managed in an unsustainable manner. For example, in Latin America, the water available per habitant has decreased by 22% in the last 20 years and millions of farmers have been affected due to droughts and lack of water availability, which threatens their crops and puts their survival at risk. Other examples are in South Asia, where per capita water availability has also decreased to 27%, and in Sub-Saharan Africa to 41% ([United Nations, 2020](#)). The implementation of the use of a reverse osmosis filtering system and the reuse of water not only represents a corrective measure to the habits of high-water consumption by the habitants of Puerto Rico, but it is also a preventive measure so that in the future, this resource will not be scarce within the island, and we will not suffer from the same problem that Latin America has today. It should be noted that wastewater treatment in Puerto Rico and the United States is regulated by the Environmental Protection Agency. This is one of the reasons why the idea of reusing wastewater after being treated by reverse osmosis looks attractive since the system represents an option to comply with the regulations.

In September 1992, the Environmental Protection Agency published a technical document providing guidelines for the treatment and reuse of water in a manner that is safe for the health of the population. This technical document is the Manual: "Guidelines for Water Reuse". This Manual is extremely important for the implementation of the reuse of wastewater after being treated since one of the main barriers that limit the implementation of this practice is precisely the population's fear of the possible risks generated to human health ([Quiñones and Guerrero, 2004](#)). Another reason to propose implementing the use of reverse osmosis in the well water and wastewater treatment process and its reuse is to support the Law for the Conservation, Development, and Use of Water Resources. This law represents a public policy of the Commonwealth approved to ensure water supply for present and future generations of Puerto Ricans. Additionally, it intends to maintain the quality and purity of Puerto Rico's waters to ensure the well-being, security, and development of the country. It also aims to prevent scarcity, misuse, waste, and pollution of such an important resource ([Government of Puerto Rico, 2022](#)). This study intends to evaluate: (a) the efficiency of the reverse osmosis system in treating well water for human use; (b) the viability of reusing wastewater after being treated by reverse osmosis; (c) the possibility of reducing the consumption of fresh water and the generation of wastewater using reverse osmosis. To accomplish these objectives, a study survey was conducted in an industrial zone in Guayama, Puerto Rico, in 2023.

MATERIALS AND METHODS

To achieve the goal of this study, the functionality of the reverse osmosis system will be evaluated based on qualitative and quantitative results obtained from an industry located in Guayama that has reverse osmosis systems to treat well water and wastewater to reuse it. Results evaluated by the industry's quality control laboratory and the statistical analysis performed on this study will determine the viability of the reuse of wastewater treated by reverse and the efficiency of the system to treat well water. Regarding the decrease in the use of fresh water and the generation of wastewater in Puerto Rico, this will depend on how viable the implementation of the reverse osmosis system is. Additional information from other investigations on different areas such as,

for example, industrial areas (pharmaceutical, textile, mining, cement, electroplating, and concrete mixers among others), agricultural areas, urban areas, and rural areas will be provided to support the results in this study.

Methods description

The following information describes the treatment applied to the waters under study (well water and wastewater) located in Guayama, Puerto Rico. The water used in the processes of an industry located in Guayama, Puerto Rico comes from a well located within its facilities. To convert well water into drinking water, the company applies different types of pre-treatments and then uses a reverse osmosis system. During reverse osmosis, the solvent passes through the semipermeable membrane from a concentrated

solution to a dilute one applying osmotic pressure (Fig. 1) (Dominighini *et al.*, 2016).

In addition, this plant also uses two other reverse osmosis systems on a smaller scale, one to purify water to use it for manufacturing (Fig. 2) while the other system is to treat said water after being used. The purpose of treating the water already used is to reuse it for cooling towers and boilers in the same company. The system used to treat wastewater is not as sophisticated as the one used to treat water that comes from the well since the intention of treating the wastewater is to reduce its conductivity and not to make it suitable for human consumption. Lowering the conductivity of water is extremely important since water with high conductivity conducts electricity more easily, which represents a risk to human life and living beings that come in contact with it.

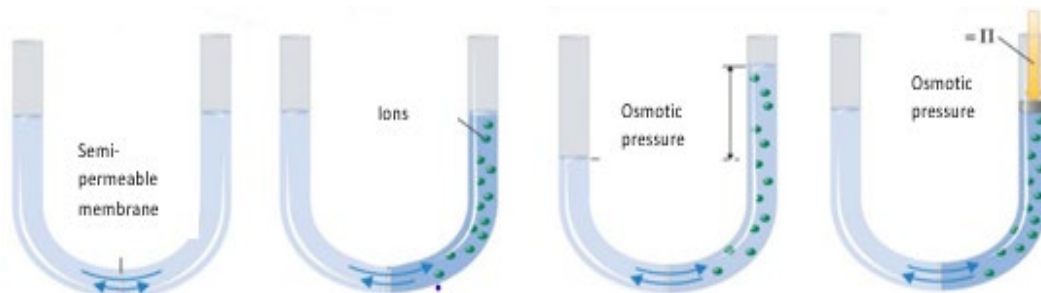


Fig. 1: Model of the operation of osmotic pressure (Solís, 2017)



Fig. 2: Smaller scale reverse osmosis system for water purification in manufacturing

The first pre-treatment used for well water is to pass it through sand filters. Sand filters remove sediment present in the water. After the water is filtered, it is stored in a tank where chlorine is added until a range of 0.3 – 0.5 ppm chlorine is obtained. This range is a Department of Health requirement for drinking water. After adding chlorine to the water, it is distributed from the tank to apply the following pre-treatments: Stage 1: Sand filter (Fig. 3), to remove traces of sediment (if any remained after the sand filter at the beginning). Stage 2: Softeners (Fig. 3), are used to remove Calcium and Magnesium which give hardness to the water. Softeners can be made of resin. This is convenient since the resin is regenerated and allows it to be reused. Stage 3: Carbon filter (Fig. 4),

this filter intends to eliminate the odor, taste, and chlorine that the water may have at this stage. Stage 4: 5-micron filter: This filter prevents the migration of resin or carbon from previous steps to subsequent steps. Stage 5: Ultraviolet Lamp: The purpose of the ultraviolet lamp is to kill microorganisms present in this stage. After the pre-treatments explained above, the water goes to the reverse osmosis system but first, it must be treated so that it has a pH of approximately 8.0 and in this way does not damage the membranes. To bring the pH of the water to 8.0, caustic soda is added, which eliminates the carbon dioxide present in the water at this stage. This system has a pH controller to confirm and maintain a constant pH value.



Fig. 3: Multimedia (sand filter) and smoothers



Fig. 4: Carbon filter

In the reverse osmosis stage, there are two membrane passes, which are: First pass (Fig. 5) intention pass is to lower the conductivity as low as possible to comply with the United States Pharmacopeia ranges and to be able to use the water in manufacturing processes and laboratories. The water before this step usually has a conductivity measurement of 350-400 micro-Siemens. The United States Pharmacopeia and quality of the plant requires that the conductivity value does not exceed 1.4 micro-Siemens. This is why in the first pass pressure is added to the osmosis system with a pump that raises around 180-200 pounds of pressure so that it can be filtered through a semi-permeable membrane. The product obtained after this step is water with conductivity values of approximately 8-10 micro-

siemens. In the second pass (Fig. 6) there are three vessels with four inches in diameter, each with three membranes inside. After this second pass, water with conductivity values of approximately 1 micron is obtained.

Although after the second pass the water already meets the USP and quality requirements for drinking water, an ionization process is applied where a resin is filtered, and positive and negative ions are eliminated. This decreases the conductivity to approximately 0.1 micron which is a value of 0. After having a conductivity value of practically 0, an ultraviolet lamp is used for bacteriological control and the water is passed to a distribution tank of 4 thousand gallons (the plant has two of these tanks). Ozone is added to the tank to eliminate any organisms present. Ozone is one of the



Fig. 5: First pass of membranes (reverse osmosis)



Fig. 6: Second pass of membranes (reverse osmosis)

common disinfectants used for this process (Grueso *et al.*, 2019) and it is necessary when a large amount of water is stored because it is pure water and pure water is susceptible to contamination. After Ozone, the water is again treated with a UV lamp to eliminate the Ozone present in it. It is important to mention that water is always in constant movement to prevent bacteria growth. At the end of the process, the water returns to the tank where there is equipment that measures the Total Organic Carbons and conductivity values. The wastewater used for manufacturing processes is discarded through pipes until it reaches a treatment plant inside the company and is stored in a tank. This industry in Guayama manufactures large quantities of vitamins and minerals, so elements such as Calcium and Magnesium (elements that give hardness to water) are present in the wastewater that is treated for reuse in boilers and cooling towers. The main objective when implementing the reverse osmosis system in the water reuse process is to reduce conductivity. In addition, it is necessary to clarify that water treated for reuse is not used for human use or consumption. The three treatments applied to wastewater are Step 1: The wastewater passes through a grinder that destroys any type of suspended solid before reaching the tank. This prevents the tank from clogging. Step 2: In the tank, the pH of the wastewater is measured, and caustic soda is added until it reaches approximately 7.5. Step 3: After obtaining the wastewater with the desired pH, it goes to the clarification tank where polymers are added to create flocs that collect the sludge or sediment and take them to the bottom of the tank. At the bottom of the tank, there is a pipe that is responsible for removing the sludge and sediment trapped by the polymers. After the three previous pre-treatments, the wastewater flows clean to a reuse pool. Already at this stage, the wastewater has adequate parameters for aqueducts (it can be eliminated through the sewer), but not for reuse in the boilers or cooling towers. So that the wastewater is in suitable conditions for reuse, pre-treatment, and reverse osmosis are applied. The pre-treatments before reverse osmosis are Stage 1: Ultrion is injected into the wastewater pool to create more flocs that trap mud and thus leave the wastewater as clean as possible. Stage 2: After applying Ultrion, the wastewater is sent to multimedia filters. Stage 3: Carbon Filter: The purpose of this stage is to remove chlorine from the wastewater so as not to damage the membranes. Stage 4: The wastewater

is sent to a tank where the anti-scaling agent is added. Stage 5: The wastewater is filtered through 5-micron Prefilters. Before the reverse osmosis process and its pre-treatments, the water received from the manufacturing processes for reuse has a conductivity of approximately 1,500 micro siemens which after the reverse osmosis process is capable of decreasing, usually generating 200 to 300 micro siemens. During the reverse osmosis process, the water passes through vessels that contain membranes with a pressure of approximately 55 psi. In the end, two water flows are obtained, one which is the rejection (unfiltered water) and the other, the processed water (permeate). Processed water or permeate as it is also known, is the water ready for use in boilers and cooling towers. The reuse system described above allows the reuse of around 500,000 gallons per month, thus reducing the number of gallons of drinking water used and the number of gallons that are discarded into the sewer. Although this system keeps working seven days a week and twenty-four hours a day, its maintenance is low-cost and occurs when the number of gallons processed and the pressure with which they come out decreases drastically. The decrease in gallons processed occurs most of the time when the membrane becomes clogged. Fortunately, the membrane can be regenerated by washing. The membranes are washed with caustic soda and involve 3 washing cycles at different pHs each (11.5, 3.5, and 7.0) accompanied by a chemical. Finally, the time of each washing cycle is 24 hours during which the system is put out of service.

Analytical framework

The goal of this study was to determine whether reverse osmosis is an effective method for treating well water and wastewater, allowing well water to be used for human consumption and wastewater to be reused for non-human consumption, thereby reducing the amount of freshwater withdrawn and wasted in Puerto Rico.

RESULTS AND DISCUSSION

The first objective of this study was to evaluate the efficiency of the reverse osmosis system in treating well water. The following results of well water treated by reverse osmosis at Guayama Industry were used to evaluate this objective.

It is important to mention that the results of [Tables 1](#) and [2](#) come from well water treated by the

Reverse osmosis system to treat well water and wastewater

Table 1: Water Results from 2022 Annual Report (Conductivity and Total Organic Carbons)

Point of use	Sampled date	Total organic carbon (ppb)	Conductivity $\mu\text{S}/\text{cm}$
HV-2116	Jan 03,2022	6	0.9
HV-2216	Jan 03,2022	6	0.4
HV-2116	Jan 17,2022	9	0.4
HV-2216	Jan 17,2022	7	0.4
SP-119	Jan 17,2022	12	0.6
HCCDI1A	Jan 31, 2022	5	0.8
HV-2116	Jan 31,2022	7	0.4
HV-2216	Jan 31,2022	12	0.6
HV-2116	Feb 14,2022	8	0.8
HV-2216	Feb 14,2022	8	0.8
SP-119	Feb 14, 2022	8	0.3
HCCDI1A	Feb 14, 2022	8	0.5
HV-2116	Mar 02,2022	15	0.4
HV-2216	Mar 02,2022	7	0.4
HV-2116	Mar 18,2022	6	0.7
HV-2216	Mar 18,2022	7	0.4
HV-2116	Mar 28,2022	3	0.6
HV-2216	Mar 28,2022	3	0.7
SP-119	Mar 28, 2022	3	0.6
HCCDI1A	Mar 28, 2022	3	0.7
HV-2116	Apr 13,2022	9	0.6
HV-2216	Apr 13,2022	4	0.7
HV-2116	Apr 29,2022	4	0.8
HV-2216	Apr 29,2022	6	0.4
SP-119	Apr 29,2022	5	0.4
HCCDI1A	Apr 29,2022	8	0.3
HV-2116	May 13,2022	13	0.6
HV-2216	May 13,2022	11	0.9
HV-2116	May 23,2022	5	0.4
HV-2216	May 23,2022	5	0.5
SP-119	May 23, 2022	9	0.5
HCCDI1A	May 23, 2022	11	0.5
HV-2116	Jun 07,2022	13	0.5
HV-2216	Jun 07,2022	9	0.6
SP-119	Jun 07,2022	13	0.6
HCCDI1A	Jun 07,2022	10	0.5
HV-2116	Jun 24,2022	8	0.9
HV-2216	Jun 24,2022	10	0.8
HV-2116	Jul 08,2022	8	0.4
HV-2216	Jul 08,2022	10	0.6
HV-2116	Jul 20,2022	12	0.8
HV-2216	Jul 20,2022	13	0.6

Continued Table 1: Water Results from 2022 Annual Report (Conductivity and Total Organic Carbons)

Point of use	Sampled date	Total organic carbon (ppb)	Conductivity $\mu\text{S}/\text{cm}$
SP-119	Jul 20,2022	16	0.7
HCCDI1A	Jul 20, 2022	11	0.8
HV-2116	Aug 05,2022	16	0.7
HV-2216	Aug 05,2022	15	0.3
HV-2116	Aug 19,2022	15	0.5
HV-2216	Aug 19,2022	11	0.6
HV-2116	Aug 29,2022	15	0.7
HV-2216	Aug 29,2022	18	0.6
SP-119	Aug 29, 2022	17	0.5
HCCDI1A	Aug 29, 2022	20	0.7
HV-2116	Sep 15,2022	8	0.6
HV-2216	Sep 15,2022	8	0.7
SP-119	Sep 15, 2022	12	0.3
HCCDI1A	Sep 15, 2022	10	0.4
HV-2116	Sep 30,2022	14	0.7
HV-2216	Sep 30,2022	15	0.5
HV-2116	Oct 11,2022	12	0.7
HV-2216	Oct 11,2022	17	0.6
HV-2116	Oct 26,2022	17	0.8
HV-2216	Oct 26,2022	15	0.9
SP-119	Oct 26,2022	25	0.9
HCCDI1A	Oct 26,2022	17	1.0
HV-2116	Nov 10,2022	20	0.8
HV-2216	Nov 10,2022	15	0.8
SP-119	Nov 10,2022	18	0.9
HCCDI1A	Nov 10, 2022	15	0.8
HV-2116	Nov 22,2022	19	0.6
HV-2216	Nov 22,2022	12	0.6
HV-2116	Dec 08,2022	8	0.9
HV-2216	Dec 08,2022	7	0.6
HV-2116	Dec 21,2022	19	1.0
HV-2216	Dec 21,2022	22	0.8
SP-119	Dec 22, 2022	20	0.3
HCCDI1A	Dec 21, 2022	29	0.8

reverse osmosis process (previously explained in the materials and methods section) at the Guayama Industry evaluated. The samples analyzed were taken on different validated water points that are periodically sampled. The samples from the water points under study were analyzed at the plant's quality control laboratory for microbiological and chemical analyses such as conductivity, Total Organic Carbons, Nitrates, and Total Aerobic Microbial Count. The Chemical results of all the samples of the year 2022 were compiled at the end of the year by a report that the company carried out to see the behavior of the system and the water quality (Tables 1 and 2). In addition, according to the annual report, a total of 77 samples were analyzed to determine the value of the Total Aerobic Microbial Count. All results for Total Aerobic Microbial Count were 0 cfu/mL. The alert level and action level in the test for Total Aerobic Microbial Count is no more than 2 cfu/mL and 100 cfu/mL respectively. Therefore, all 77 samples met the Microbiology Specification Limits. The results in Table 1 showed a total of 76 results from 4 different water points (HV-2116, HV2216, SP-119, and HCCDI1A), and each point was shown at least once a

month. The range of Total Organic Carbons (TOC) in the sample was from 3 to 29 ppb. Total organic carbon is a measure of organic molecules present in waters measured by the pharmaceutical as carbon (US Pharmacopeia, 2023). According to Beckman Coulter (2023), reagent water cannot contain a total organic carbons level of more than 0.10 mg/L (0.10mg/L = 100 ppb). Reagent water is water without impurity, and it is a suitable water for human consumption. Since the highest value of total organic carbons results (Table 1) was 29 ppm and the maximum possible value according to Beckman Coulter is 100, it is appropriate to establish that treating well water with a reverse osmosis system produced water suitable for human consumption. For the conductivity, the range obtained was from 0.3 to 1.0 $\mu\text{S}/\text{CM}$ (Table 1). The conductivity range of water for domestic use is from 400 to 800 $\mu\text{S}/\text{cm}$ and for distilled water is 0.5 a 2.0 $\mu\text{S}/\text{cm}$ (US Geological Survey, 2019). The highest conductivity result obtained in Table 2 was 1.0 $\mu\text{S}/\text{cm}$, therefore it can be established that the reverse osmosis system used to treat well water produces distilled water which is suitable for human use and is even purer than domestic water (drinking water). The

Table 2: Water Results from 2022 Annual Report (Nitrate)

POINT OF USE	SAMPLED DATE	COMPONENT NAME	RESULTS
HV-2116	Jan 17, 2022	Nitrate	Conforms
HV-2216	Jan 17, 2022	Nitrate	Conforms
SP-119	Jan 17, 2022	Nitrate	Conforms
HCCDI1A	Jan 31, 2022	Nitrate	Conforms
HV-2116	Apr 29,2022	Nitrate	Conforms
HV-2216	Apr 29,2022	Nitrate	Conforms
SP-119	Apr 29,2022	Nitrate	Conforms
HCCDI1A	Apr 29,2022	Nitrate	Conforms
HV-2116	Jul 20, 2022	Nitrate	Conforms
HV-2216	Jul 20, 2022	Nitrate	Conforms
SP-119	Jul 20, 2022	Nitrate	Conforms
HCCDI1A	Jul 20, 2022	Nitrate	Conforms
HV-2116	Oct 26,2022	Nitrate	Conforms
HV-2216	Oct 26,2022	Nitrate	Conforms
SP-119	Oct 26,2022	Nitrate	Conforms
HCCDI1A	Oct 26,2022	Nitrate	Conforms

results in Table 2 showed a total of 16 results from the same 4 points analyzed in Table 1. The object under analysis in this table determined the presence of nitrate in the well water treated by reverse osmosis. Drinking water with High levels of nitrate can cause health effects such as the following

- (a) *Blue baby syndrome (or methemoglobinemia), which is a decrease in the blood's ability to carry oxygen to the tissues;*
- (b) *Recurrent respiratory infections;*
- (c) *Thyroid dysfunction;*
- (d) *Adverse reproductive outcomes, such as abortions spontaneous;*
- (e) *Certain cancers, including stomach or bladder*

cancer (Oregon Health Authority, 2022).

The analysis of Table 2 shows that all samples analyzed met the laboratory specification limits which should be no more than 0.2 ppm (0.2 mg/l) of Nitrates established by industry specifications. The federal government has established that the safe drinking water standard (also called maximum contaminant level) corresponding to nitrate is 10 mg/l (Oregon Health Authority, 2022). After evaluation of all parameters in Tables 1 and 2 (total organic carbon, conductivity, and the nitrate presence) and the Total Aerobic Microbial Count could be seen that all well water samples treated by reverse osmosis met the necessary conditions to be classified as suitable for

Table 3: Reverse osmosis for wastewater treatment year 2018- Cations (Results)

Cations	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
Aluminium (Al)	<0.06 mg/L	<0.06 mg/L
Barium (Ba)	0.037 mg/L	0.037 mg/L
Boron (B)	0.12 mg/L	0.12 mg/L
Cadmium (Cd)	<0.011 mg/L	<0.011 mg/L
Calcium (Ca)	57 mg/L	19 mg/L
Calcium Carbonate (CaCO ₃)	140 mg/L	40 mg/L
Chromium (Cr)	<0.032 mg/L	<0.032 mg/L
Copper (Cu)	<0.06 mg/L	<0.06 mg/L
Iron (Fe)	<0.04 mg/L	<0.04 mg/L
Lead (Pb)	<0.21 mg/L	<0.21 mg/L
Lithium (Li)	0.011 mg/L	0.011 mg/L
Magnesium (Mg)	26 mg/L	14 mg/L
Magnesium Carbonate (MgCO ₃)	110 mg/L	40 mg/L
Manganese (Mn)	<0.011 mg/L	<0.011 mg/L
Molybdenum (Mo)	<0.08 mg/L	<0.08 mg/L
Nickel (Ni)	<0.02 mg/L	<0.02 mg/L
Phosphorus (P)	0.19 mg/L	0.18 mg/L
Potassium (K)	12 mg/L	8 mg/L
Silicon (Si)	20 mg/L	19 mg/L
Silica (SiO ₂)	43 mg/L	42 mg/L
Sodium (Na)	350 mg/L	40 mg/L
Sodium Carbonate (NaCO ₃)	750 mg/L	78 mg/L
Strontium (Sr)	0.177 mg/L	0.025 mg/L
Vanadium (V)	<0.02 mg/L	<0.02 mg/L
Zinc (Zn)	0.03 mg/L	0.03 mg/L

human consumption. This follows the study that the use of an osmosis system to treat different water sources (e.g., groundwater, seawater, and well water) allows for obtaining water suitable for human consumption (Ruiz and Coronado, 2016; Romero *et al.*, 2015; Guevara *et al.*, 2022; Devora *et al.*, 2016). The second objective of this study was to evaluate the viability of reusing wastewater in Puerto Rico after being treated by reverse osmosis. The following results of wastewater treated by reverse osmosis at Guayama Industry were used to evaluate this objective.

Tables 3, 4, and 5 correspond to the results of wastewater before and after being treated by reverse osmosis in 2018 year. Tables 6, 7, and 8 show the before and after results of wastewater treated using reverse osmosis in 2019. Some results for the concentration of cations and anions from Tables 3, 4, 6, and 7 were used to create Table 9 and to perform the following statistical analysis. Missing values of cations and anions in Table 9 were not selected

for analysis because they are reported based on a range (e.g. <0.006 mg/L) and not at an exact concentration. Table 9 presents the data used for the Paired T-Test statistical analysis in Table 11. Table 10 shows conductivity values recorded before and after pretreatments and reverse osmosis in June and July 2023.

For the statistical analysis presented in Table 11, the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is > than 0.011289425 ($P(T \leq t)$ one-tail value) and 2.494192558 (t Stat) > 1.734063607 (t Critical one-tail). Therefore, the null hypothesis is rejected. This shows that there are differences between the concentrations of anions and cations present in the wastewater before and after being treated by reverse osmosis. The data reflects that the values are lower after Reverse Osmosis treatment. Therefore, and according to this statistical analysis, it is appropriate to

Table 4: Reverse osmosis for wastewater treatment year 2018- Anions (Results)

Anions	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
Chloride (Cl)	180 mg/L	40 mg/L
Nitrite (NO ₂)	<2.0 mg/L	<2.0 mg/L
Bromide (Br)	<2.0 mg/L	<2.0 mg/L
Nitrate (NO ₃)	<2.0 mg/L	<2.0 mg/L
Sulfate (SO ₄)	190 mg/L	65 mg/L
Chloride Carbonate (ClCO ₃)	250 mg/L	70 mg/L
Nitrate Carbonate (NCO ₃)	<1.6 mg/L	<1.6 mg/L
Sulphate Carbonate ([SO ₄]CO ₃)	190 mg/L	66 mg/L

Table 5: Reverse osmosis for wastewater treatment year 2018 - Other analytes (Results)

Other Analytes	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
pH @ 25°C	8.1 pH Units	8.4 pH Units
Conductivity at 25°C	1800 µS/cm	490 µS/cm
Total, Hardness (CaCO ₃)	250 mg/L	70 mg/L
Ammonia (NH ₃)	9.1 mg/L	0.15 mg/L
Ammonia Carbonate ([NH ₄]2CO ₃)	27 mg/L	0.36 mg/L
Ortho Phosphate (PO ₄)	<0.1 mg/L	<0.1 mg/L
Phenolphthalein Alkalinity (CaCO ₃)	<10 mg/L	<10 mg/L

say that the Reverse Osmosis process was efficient for the removal of anions and cations from wastewater.

For the statistical analysis presented in Table 12, the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is > than 0.012667005 ($P(T \leq t)$ one-tail value) and 2.438574541 (t Stat) > 1.734063607 (t Critical one-tail). Therefore, the null hypothesis is rejected. This shows that there are differences between the concentrations of anions and cations present in the wastewater before and after being treated by reverse osmosis. The data reflects that the values are lower

after reverse osmosis treatment. Therefore, and according to this statistical analysis, it is appropriate to say that the Reverse Osmosis process was efficient for the removal of anions and cations from wastewater.

For the statistical analysis presented in Table 13, the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is < than 0.051902856 ($P(T \leq t)$ one-tail value) and -1.713416519 (t Stat) < 1.734063607 (t Critical one-tail). Therefore, the null hypothesis is accepted. This shows that there are practically no differences between the concentrations of anions and cations

Table 6: Reverse osmosis for wastewater treatment year 2019- Cations (Results)

Cations - Metal	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
Aluminium (Al)	<0.03 mg/L	<0.03 mg/L
Barium (Ba)	0.020 mg/L	0.020 mg/L
Boron (B)	0.54 mg/L	0.53 mg/L
Cadmium (Cd)	<0.005 mg/L	<0.005 mg/L
Calcium (Ca)	41 mg/L	13 mg/L
Calcium Carbonate (CaCO ₃)	100 mg/L	25 mg/L
Chromium (Cr)	<0.016 mg/L	<0.016 mg/L
Copper (Cu)	0.08 mg/L	0.06 mg/L
Iron (Fe)	<0.02 mg/L	<0.02 mg/L
Lead (Pb)	<0.11 mg/L	<0.11 mg/L
Lithium (Li)	0.012 mg/L	0.11 mg/L
Magnesium (Mg)	26 mg/L	13 mg/L
Magnesium Carbonate (MgCO ₃)	110 mg/L	39 mg/L
Manganese (Mn)	<0.005 mg/L	<0.005 mg/L
Molybdenum (Mo)	<0.08 mg/L	<0.08 mg/L
Nickel (Ni)	<0.01 mg/L	<0.01 mg/L
Phosphorus (P)	0.48 mg/L	0.45 mg/L
Potassium (K)	10 mg/L	4 mg/L
Silicon (Si)	21 mg/L	20 mg/L
Silica (SiO ₂)	46 mg/L	44 mg/L
Sodium (Na)	420 mg/L	59 mg/L
Sodium Carbonate (NaCO ₃)	910 mg/L	83 mg/L
Strontium (Sr)	0.158 mg/L	0.035 mg/L
Vanadium (V)	<0.01 mg/L	<0.01 mg/L
Zinc (Zn)	0.02 mg/L	0.02 mg/L

Table 7: Reverse osmosis for wastewater treatment year 2019- Anions (Results)

Anions	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
Chloride (Cl)	280 mg/L	55 mg/L
Nitrite (NO ₂)	<2.0 mg/L	<2.0 mg/L
Bromide (Br)	<2.0 mg/L	<2.0 mg/L
Nitrate (NO ₃)	<2.0 mg/L	<2.0 mg/L
Sulfate (SO ₄)	180 mg/L	58 mg/L
Chloride Carbonate (ClCO ₃)	390 mg/L	61 mg/L
Nitrate Carbonate (NCO ₃)	<1.6 mg/L	<1.6 mg/L
Sulphate Carbonate ([SO ₄]CO ₃)	190 mg/L	60 mg/L

Table 8: Reverse osmosis for wastewater treatment year 2019 - Other analytes (Results)

Other Analytes	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
pH @ 25°C	8.1 pH Units	8.5 pH Units
Conductivity at 25°C	2200 µS/cm	540 µS/cm
Total, Hardness	210 mg/L	55 mg/L
Ammonia (NH ₃)	9.2 mg/L	0.14 mg/L
Ammonia Carbonate ([NH ₄]2CO ₃)	25 mg/L	0.40 mg/L
Ortho Phosphate (PO ₄)	0.7 mg/L	0.3 mg/L
Phenolphthalein Alkalinity	11 mg/L	11 mg/L

present in wastewater before being treated by reverse osmosis from the years 2018 and 2019.

For the statistical analysis presented in [Table 14](#), the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is > than 0.427047 (P(T<=t) one-tail value) and -0.186559(t Stat) < 1.734064 (t Critical one-tail). Therefore, the null hypothesis is accepted. This shows that there are practically no differences between the concentrations of anions and cations present in wastewater after being treated by reverse osmosis in the years 2018 and 2019. Finally, with this result, it can be said that the removal process of anions and cations is one consistent over time. With the result of the previous 4 statistical analyses, it is appropriate to establish that the reverse osmosis system is efficient for the removal of anions and cations from wastewater. Is important to mention that the reused water must have certain characteristics according to

the place where it will be used. In this case, the most important characteristic evaluated to determine if water can be reused in cooling towers and boilers was conductivity. [Table 10](#) presents the wastewater conductivity results obtained before and after pretreatments and reverse osmosis during June and July 2023. The range of conductivity obtained before reverse osmosis was 1339 to 1525 micro-Siemens during June 2023 and 1336 to 1555 micro-Siemens for July 2023. For samples after reverse osmosis, the range obtained was 181 to 475 micro-Siemens during June 2023 and 209 to 618 micro-Siemens for July 2023. In addition, statistical analysis for Paired T-test was performed from the data of [Table 10](#), refer to [Tables 15](#) and [16](#). The company's utility supervisor let it be known that although conductivity ranges in wastewater after treatment are generally from 200 to 300 micro-Siemens, the obtained ranges from June and July 2023 after reverse osmosis are acceptable for reuse in cooling towers and boilers. Therefore, it is appropriate to say that the use of a reverse

Table 9: Values used for the paired T-Test associated with results of Anions and Cations before and after the wastewater is treated by reverse osmosis

Anion or Cation	Water (before reverse osmosis) 2018	Water (after reverse osmosis) 2018	Water (before reverse osmosis) 2019	Water (after reverse osmosis) 2019
Barium (Ba)	0.037 mg/L	0.037 mg/L	0.020 mg/L	0.020 mg/L
Boron (B)	0.12 mg/L	0.12 mg/L	0.54 mg/L	0.53 mg/L
Calcium (Ca)	57 mg/L	19 mg/L	41 mg/L	13 mg/L
Calcium Carbonate (CaCO ₃)	140 mg/L	40 mg/L	100 mg/L	25 mg/L
Lithium (Li)	0.011 mg/L	0.011 mg/L	0.012 mg/L	0.11 mg/L
Magnesium (Mg)	26 mg/L	14 mg/L	26 mg/L	13 mg/L
Magnesium Carbonate (MgCO ₃)	110 mg/L	40 mg/L	110 mg/L	39 mg/L
Phosphorus (P)	0.19 mg/L	0.18 mg/L	0.48 mg/L	0.45 mg/L
Potassium (K)	12 mg/L	8 mg/L	10 mg/L	4 mg/L
Silicon (Si)	20 mg/L	19 mg/L	21 mg/L	20 mg/L
Silica (SiO ₂)	43 mg/L	42 mg/L	46 mg/L	44 mg/L
Sodium (Na)	350 mg/L	40 mg/L	420 mg/L	59 mg/L
Sodium Carbonate (NaCO ₃)	750 mg/L	78 mg/L	910 mg/L	83 mg/L
Strontium (Sr)	0.177 mg/L	0.025 mg/L	0.158 mg/L	0.035 mg/L
Zinc (Zn)	0.03 mg/L	0.03 mg/L	0.02 mg/L	0.02 mg/L
Chloride (Cl)	180 mg/L	40 mg/L	280 mg/L	55 mg/L
Sulfate (SO ₄)	190 mg/L	65 mg/L	180 mg/L	58 mg/L
Chloride Carbonate (ClCO ₃)	250 mg/L	70 mg/L	390 mg/L	61 mg/L
Sulphate Carbonate (SO ₄]CO ₃)	190 mg/L	66 mg/L	190 mg/L	60 mg/L

osmosis system to treat wastewater allows the reuse of said water in other processes such as the cooling of towers and boilers.

For the statistical analysis presented in Table 15, the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is > than 3.68E-27 (P(T<=t) one-tail value) and 47.76286 (t Stat) > 1.705618 (t Critical one-tail). Therefore, the null hypothesis is rejected. This shows that there are differences between the conductivity before and after being treated by reverse osmosis. The data reflects that the values are lower after reverse osmosis treatment. Therefore, and according to this statistical analysis, it is appropriate to say that the reverse osmosis process was efficient in reducing the conductivity of the water.

For the statistical analysis presented in Table

16, the null hypothesis was used (it is assumed that both variables are equal, in other words, that there is no difference between both variables) and 0.05 as the alpha value. So: 0.05 (alpha value) is > than 5.72E-37 (value of P(T<=t) one-tail) and 80.84255 (t Stat) > 1.697261 (t Critical one-tail). Therefore, the null hypothesis is rejected. This shows that there are differences between the concentrations of anions and cations present in the wastewater before and after being treated by reverse osmosis. The data reflects that the values are lower after reverse osmosis treatment. Therefore, and according to this statistical analysis, it is appropriate to say that the reverse osmosis process was efficient for the removal of anions and cations from wastewater. This study's finding is consistent with the effectiveness of reverse osmosis as a treatment for post-treatment wastewater reuse (Calderon *et al.*, 2017; Calvo *et al.*, 2011; Duque and Donato, 2020; Nazer *et al.*, 2018; Reina, M., 2018; Ruiz, R., 2019,

Partal et al., 2022; Engstler et al., 2022). The third objective of this study was to evaluate the possibility of reducing the consumption of fresh water and the generation of wastewater using reverse osmosis). The results of gallons reuse treated by reverse osmosis at

Guayama Industry were used to evaluate this objective (Table 17).

Table 17 presents the quantity of gallons of water reused in cooling towers and boilers. The gallons results were as follows: 325,000 gallons in February,

Table 10: Conductivity values obtained before and after pretreatments and reverse osmosis during June and July 2023

Day	Conductivity in June (before reverse osmosis) micro siemens	Conductivity in June (after reverse osmosis) micro siemens	Conductivity in July (before reverse osmosis) micro siemens	Conductivity in July (after reverse osmosis) micro siemens
1	1447	360	1412	209
2	1441	340	1411	237
3	1369	405	1415	250
4	1395	403	1436	248
5	1339	337	1398	248
6	1446	387	1355	225
7	**	**	1347	228
8	**	**	1336	237
9	**	**	1336	233
10	1436	370	1419	259
11	1459	475	1394	264
12	1478	461	1554	295
13	1447	449	1555	304
14	1439	404	1501	286
15	1503	399	1473	352
16	1411	288	1432	618
17	1377	303	1470	295
18	1396	206	1461	328
19	1402	454	1371	273
20	1397	377	1394	388
21	1400	406	1458	315
22	1407	389	1497	337
23	1436	260	1496	306
24	1445	190	1486	312
25	1449	229	1486	270
26	1524	193	1460	287
27	1522	195	1458	296
28	1525	198	1434	339
29	1467	191	1450	308
30	1394	181	1485	314
31	N/A	N/A	1491	323

393,000 gallons in March, 369,000 in April, 397,000 in May, 395,000 in July, 453,000 in July, and 65,000 in August. This represented a total of 2,397,000 gallons of fresh water that were not consumed and 2,397,000 gallons of wastewater that were not discarded into the sewer. The highest amount of water reused was 453,000 gallons in July 2023, while the lowest was 325,000 gallons in February. It is necessary to mention that during February,

the system was turned off for 3 days due to a leak in the inlet pump and the month had fewer days, which is why the value of reused gallons decreased by 128,000 gallons compared to July. The daily range of water reuse with the reverse osmosis system was 8,000 to 19,000 gallons. According to the company's utility supervisor, this system can reuse up to 550,000 gallons per month. In addition, a Pearson test was performed using data from [Table 17](#) ([Table 18](#)).

Table 11: Paired T-Test for Cations and Anions from Water Analysis 2018 (Data from [Table 9](#) - before reverse osmosis 2018 versus after reverse osmosis 2018)

Statistical Parameter	Raw Water (before reverse osmosis)	Filtered (after reverse osmosis)
mean	122.0297368	28.49489474
Variance	33732.45597	737.9904622
Observations	19	19
Pearson Correlation	0.776664572	
Hypothesized Mean Difference	0	
df	18	
tStat	2.494192558	
P(T<=t) one-tail	0.011289425	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.022578849	
t Critical two-tail	2.10092204	

T-Test: Paired Two Sample for Means

Table 12: Paired T-Test for Cations and Anions from Water Analysis 2019 (Data from [Table 9](#) - before reverse osmosis 2019 vs after reverse osmosis 2019)

Statistical Parameter	Raw Water (before reverse osmosis) 2019	Filtered (after reverse osmosis) 2019
mean	143.4331579	28.16657895
Variance	52207.01128	769.0405724
Observations	19	19
Pearson Correlation	0.830526593	
Hypothesized Mean Difference	0	
df	18	
tStat	2.438574541	
P(T<=t) one-tail	0.012667005	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.025334009	
t Critical two-tail	2.10092204	

T-Test: Paired Two Sample for Means

To apply the Pearson test to the data in Table 17, the values of the reused gallons for March, May, and July were selected since these months had the same number of days and within them, there was no interruption for the reuse of gallons. To determine the correlation value of the lines in Table 18, the following ranges were used:

- $r = 1$; perfect linear correlation
- $0.8 < r < 1$ = very high linear correlation
- $0.6 < r < 0.8$ = high linear correlation
- $0.4 < r < 0.6$ = moderate linear correlation
- $0.2 < r < 0.4$ = low linear correlation
- $0 < r < 0.2$ = very low linear correlation
- $r = 0$; null linear correlation

Table 13: Paired T-Test for Cations and Anions from Water Analysis 2018 (Data from Table 9- before reverse osmosis 2018 vs before reverse osmosis 2019)

Statistical Parameter	Raw Water (before reverse osmosis) 2018	Raw Water (before reverse osmosis) 2019
mean	122.0297368	143.4331579
Variance	33732.45597	52207.01128
Observations	19	19
Pearson Correlation	0.98861495	
Hypothesized Mean Difference	0	
df	18	
tStat	-1.713416519	
P(T<=t) one-tail	0.051902856	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.103805711	
t Critical two-tail	2.10092204	

T-Test: Paired Two Sample for Means

Table 14: Paired T-Test for Cations and Anions from Water Analysis 2018 (Data from Table 9- after reverse osmosis 2018 vs after reverse osmosis 2019)

Statistical Parameter	Filtered (after reverse osmosis) 2018	Filtered (after reverse osmosis) 2019
mean	28.49489	28.16658
Variance	737.9905	769.0406
Observations	19	19
Pearson Correlation	0.961157	
Hypothesized Mean Difference	0	
df	18	
tStat	0.186559	
P(T<=t) one-tail	0.427047	
t Critical one-tail	1.734064	
P(T<=t) two-tail	0.854093	
t Critical two-tail	2.100922	

T-Test: Paired Two Sample for Means

According to the results in [Table 18](#), March and May obtained a low linear correlation, March, and July a very low correlation, and May and July a high linear correlation. Therefore, May and July are the results with the greatest linear correlation.

The results of this study showed that reverse osmosis is an effective system for treating well water for human use and enabling the reuse of wastewater after treatment. A total of 2,397,000 gallons of wastewater were treated and reused for cooling towers and boilers ([Table 17](#)), representing the same

amount of freshwater conserved and wastewater not discharged into the sewer system. The metrics analyzed were total organic carbon, conductivity, nitrate levels, and total aerobic microbial population. Total organic carbon in the samples ranged from 3 to 29 ppb and conductivity was between 0.3 $\mu\text{S}/\text{CM}$ and 1.0 $\mu\text{S}/\text{CM}$ ([Table 1](#)). Nitrate levels were all under 0.2 ppm (0.2 mg/l) ([Table 2](#)). Total aerobic bacteria counts were 0 cfu per milliliter. Regarding the feasibility of reusing wastewater post-reverse osmosis treatment, the findings showed decreased levels of anions and

Table 15: Paired T-test for Conductivity in June (before reverse Osmosis) vs Conductivity in June (after reverse osmosis)
(Data from [Table 10](#))

Statistical Parameter	June (before reverse osmosis)	June (after reverse osmosis)
mean	1435.222	327.7778
Variance	2279,872	9794.41
Observations	27	27
Pearson Correlation	-0.25829	
Hypothesized Mean Difference	0	
df	26	
tStat	47.76286	
P(T<=t) one-tail	3.68E-27	
t Critical one-tail	1.705618	
P(T<=t) two-tail	7.36E-27	
t Critical two-tail	2.055529	

T-Test: Paired Two Sample for Means

Table 16: Paired T-Test for Conductivity in July (before reverse osmosis) vs Conductivity in July (after reverse osmosis) (Data from [Table 10](#))

Statistical Parameter	July (before reverse osmosis)	July (after reverse osmosis)
mean	1441	296.2581
Variance	3326.733	5349.465
Observations	31	31
Pearson Correlation	0.291616	
Hypothesized Mean Difference	0	
df	30	
tStat	80.84255	
P(T<=t) one-tail	5.72E-37	
t Critical one-tail	1.697261	
P(T<=t) two-tail	1.14E-36	
t Critical two-tail	2.042272	

T-Test: Paired Two Sample for Means

Table 17: Gallons of reused water during the year 2023

Day	Reuse for February (gallons)	Reuse for March (gallons)	Reuse for April (gallons)	Reuse for May (gallons)	Reuse for June (gallons)	Reuse for July (gallons)	Reuse for August (gallons)
1	15,000	11,000	12,000	15,000	11,000	18,000	13,000
2	15,000	11,000	15,000	15,000	11,000	19,000	13,000
3	12,000	15,000	14,000	15,000	11,000	16,000	9,000
4	13,000	15,000	12,000	15,000	11,000	17,000	0*
5	0**	15,000	13,000	15,000	9,000	17,000	0*
6	0**	8,000	13,000	15,000	13,000	16,000	0*
7	0**	8,000	12,000	15,000	0**	19,000	0*
8	17,000	16,000	12,000	15,000	0**	17,000	0*
9	17,000	8,000	9,000	15,000	0**	16,000	0*
10	14,000	9,000	12,000	15,000	14,000	17,000	4,000
11	12,000	17,000	9,000	15,000	17,000	16,000	10,000
12	13,000	17,000	9,000	15,000	15,000	14,000	8,000
13	13,000	12,000	9,000	15,000	15,000	10,000	18,000
14	13,000	17,000	8,000	15,000	13,000	13,000	0**
15	17,000	17,000	8,000	15,000	12,000	16,000	0**
16	10,000	15,000	8,000	15,000	13,000	16,000	0**
17	12,000	15,000	8,000	15,000	13,000	15,000	0**
18	12,000	15,000	11,000	12,000	13,000	15,000	0**
19	12,000	15,000	12,000	12,000	17,000	10,000	0**
20	10,000	18,000	11,000	12,000	18,000	14,000	0**
21	16,000	18,000	11,000	12,000	17,000	14,000	0**
22	16,000	17,000	15,000	11,000	17,000	14,000	0**
23	15,000	17,000	15,000	11,000	12,000	13,000	0**
24	15,000	8,000	15,000	10,000	18,000	13,000	0**
25	10,000	8,000	15,000	10,000	15,000	11,000	0**
26	10,000	8,000	15,000	9,000	20,000	14,000	0**
27	8,000	12,000	15,000	9,000	18,000	13,000	0**
28	8,000	11,000	18,000	9,000	18,000	13,000	0**
29	N/A	11,000	18,000	9,000	18,000	13,000	0**
30	N/A	9,000	15,000	8,000	16,000	13,000	0**
31	N/A	9,000	N/A	8,000	N/A	11,000	0**
Total, gallons (by month)	325,000	393,000	369,000	397,000	395,000	453,000	65,000
Total gallons (all months)	2,397,000						

*reverse osmosis shutdown CIP cleaning. ** reverse osmosis off liquefaction in inlet pump.

cations in the treated wastewater (Tables 3, 4, 6, and 7). Additionally, all reverse osmosis-treated well water samples tested in 2022 met the quality control laboratory criteria.

CONCLUSION

Freshwater, comprising only 2.5% of Earth's total water, stands as a crucial yet finite resource, indispensable for various industries including pharmaceuticals, textiles, food production, and agriculture. The effective disposal of wastewater from these sectors is imperative to meet environmental standards. This study aimed to assess the efficacy of reverse osmosis systems in treating well water for human consumption, investigating the potential for reusing treated wastewater, and

Table 18: Results for Pearson test (data from Table 17)

Months	Correlation
March and May	0.309645
March and July	0.013738
May and July	0.631223

evaluating the feasibility of reducing both freshwater consumption and wastewater generation. Through the analysis of qualitative and quantitative data collected from the manufacturing industry in Guayama, Puerto Rico, spanning the years 2018, 2019, 2022, and 2023, statistical analyses were conducted utilizing the Paired T-Test and Pearson correlation tests with Minitab Statistical Software (Version 21.1.0). The findings demonstrate the effectiveness of RO systems

in treating well water for human use and underscore the feasibility of reusing treated wastewater for non-consumptive purposes, such as in cooling towers and boilers, resulting in a significant reduction in both freshwater consumption and wastewater disposal. The study successfully addressed its research question by confirming that the implementation of reverse osmosis systems can substantially reduce freshwater extraction in Puerto Rico. Furthermore, it achieved its goals of evaluating the treatment effectiveness of well water, exploring wastewater reuse potential, and reducing freshwater use and wastewater production. The results underscore the urgent need to adopt sustainable water management practices to mitigate the overexploitation and pollution of freshwater resources, vital for socioeconomic development, food and energy production, ecosystem health, and human survival. Essential measures include enhancing hydraulic infrastructure, managing water resources efficiently, deploying innovative technologies, and conducting public awareness campaigns. Educating citizens and stakeholders about the repercussions of unsustainable water use and providing support systems can foster sustainable economic development and prevent environmental degradation. In conclusion, this research affirms the efficacy of reverse osmosis systems in treating well water and wastewater, highlighting their potential for sustainable water management. The study validates that RO-treated well water meets quality standards for human consumption, and the reuse of treated wastewater in industrial applications significantly curtails freshwater consumption and wastewater discharge. Notably, the reuse of 2,397,000 gallons of wastewater conserves an equivalent amount of freshwater, contributing to environmental sustainability. While these findings suggest reverse osmosis technology as a promising solution for addressing water scarcity, further research is warranted to optimize processes and ensure long-term safety and efficiency.

AUTHOR CONTRIBUTIONS

A. Meléndez-Rivera performed the literature review, analyzed, and interpreted the data. Dr. J.C. Musa-Wasil reviewed research proposals, goals, and literature content. Dr. K. J. Malave-Llamas evaluated statistical analysis and Prof. D. K. Almestica-Martinez reviewed and edited the wording, formatting, citing, and referencing.

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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)

UV	Ultraviolet
USP	United States Pharmacopeia
TOC	Total Organic Carbons
PPB	Part Per Billions

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ORIGINAL RESEARCH PAPER

On the master plan conformance with urban reality: A comparative assessment

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ABSTRACT

BACKGROUND AND OBJECTIVES: The gap between urban planning and its implementation in cities has led to the evaluation of urban plans which heightens the efficiency of plans. This research evaluates the dissimilarities between the city's reality and planned prospects.

METHODS: To assess that, the Delphi technique was utilized to determine the criteria then Geographic Information System and quantitative models namely Mean Center, Standard Deviation Ellipse, and Planning Implementation Rate were employed.

FINDINGS: The outcomes reveal that Mashhad's direction of urban development corresponds to the master plan. The second estimated alternative for the population (with 83.52%) has a high level of conformity. On the subject of land use, conforming and non-conforming uses account for 47% and 23.80% respectively. A preponderance of non-conforming uses is in the south-to-east, north, and northwest parts of the city, and zone 7 accommodates the highest area of non-conforming uses among other zones. The implementation rate is 94.7%, showing that the current urban forms were implemented following the master plan to a large extent. However, the construction outside the city's limit is not under regulation. Three areas with high density located in the west, northwest, and east (Bahonar town) have the highest level of non-conformity.

CONCLUSION: The master plan could not achieve its street network goal due to an approximately 58% mismatch with the existing network. As a result, the conflicts in spatial findings could have been shaped by the implementation or inattention to planning regulations.

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INTRODUCTION

Calkins (1979), defined planning as a spatially oriented activity that distributes activities across some space. Failure to implement plans has long been considered a significant barrier to effective planning (Berke *et al.*, 2006), even if it leads to progressive devaluation of the urban plans as the main product of planning activity and the basic support mechanism to control the form of the city (Oliveira and Pinho, 2010). Therefore, defining planning as control of the future implies that planning will not be successful without evaluation and conformity (Alexander and Faludi, 1989). Evaluation is a complex action that considers performance-related factors to study the effectiveness of plans and reveal operational setbacks (Ghodrati, 2002). Talen (1996) categorized the planning evaluation into four types: evaluation before plan implementation, evaluation of planning practice, policy implementation analysis, and the evaluation of the implementation of plans. Urban planning implementation evaluation can systematically analyze, supervise, and inspect planning implementation also, it can be employed to promptly rectify the deviation between planning implementation and expectation brought about by the uncertainties of urban development and intrinsic defects of urban planning (Calkins, 1979; Li *et al.*, 2022). Two divergent definitions were proposed by Laurian *et al.* (2004) to evaluate plan implementation: performance-based and conformance-based. The conformance-based approach focuses on planning outcomes and the linkages between plans and actual development to articulate to what degree implementation decisions, and outcomes conform to the objectives expressed in the plan being evaluated, so it is crystal clear that conformance-based evaluation views the literal realization of a plan's goals as important; however, the performance-based method centers on planning processes and considers the plan as a guide for future planning decisions, rather than a blueprint (Alexander and Faludi, 1989; Ryan and Gao, 2019; Laurian *et al.*, 2004). Thus, evaluation can be applied as an aid to monitor implementation and provide a foundation for further improvements.

Implementation may be viewed as a process of interaction between the setting goals and actions geared to achieving them. Over time, new forces emerge in urban environments, leading to changes in the plans (Alterman, 1979); for instance, in theory,

physical developments should conform to the plan's proposals; however, inevitably, plans and outcomes do not match perfectly resulting in areas of non-conformance which will represent a gap between planning theory and practice or an ineffective planning system (Qian, 2013). In general, Alterman and Hill (1978) defined three broad facets associated with the degree of implementation political-institutional factors, attributes of the plan (Flexibility and Plan age), and urban system factors. They proved that the greater the flexibility of the plan, the lesser the likelihood of deviation from it, also the magnitude of the deviation in a plan is directly related to time (Plan age). The application of regulations, disbursement of funds, contracting and procurement, personnel actions and management, service delivery, resource allocations (Alexander and Faludi, 1989), the commitment of the agency, management techniques, and application of management techniques by developers (Laurian *et al.*, 2004) are also several elements leading to plan implementation. Furthermore, Mehdizadeh *et al* (2015) classified the defects and shortages in urban plans into three categories in terms of theory, methodology, and implementation. Mashhoodi (1944), takes the view that providing strategy and general suggestions suitable to current capabilities (generalization), not providing quantitative economic predictions, inflexibility, lack of financial resources and public participation, and poor statistical information are reasons leading to non-conformity. Table 1 reveals the conducted studies examining the reasons and main obstacles hindering the implementation of plans. It appears that legal and enforcing barriers, paying no attention to the land, human, and capital resources, generalized outlook, and people's ignorant acts are fundamental parameters producing non-conformances (Table 1).

As defined by Cowan (2005), a master plan is a scheme showing how a site can be developed which not only charts the process but also explains how a site will be developed and prepared by or on behalf of an organization that owns the site or controls the development process. The purpose of that is to set out principles on matters of importance, not to prescribe in detail how development should be designed (Cowan, 2002). Therefore, it reflects the central-local government policy visions of the ideal direction for a city's growth in terms of demographic, economic, and social objectives. Although the master plan is

Table 1: Overview of the recent research into factors influencing non-conformity of the urban plan

Authors	Factors
Li <i>et al.</i> , (2022)	✓ Planning contents are not aligned with the carrying capacity of resources, environment, and the evaluation of the suitability of land
Shen <i>et al.</i> , (2021)	✓ Land resources
	✓ Saturated development or the fragmentation of neighboring land
Menzori, Sousa and Gonçalves (2021)	✓ The absence of planning regulations, characterizing contrasting approaches to territorial governance
	✓ Legal and economic barriers
Ryan and Gao (2019)	✓ Comprehensive Plan does not seem to have been publicized or understood as a strategic plan
	✓ A plan that is comparatively unspecific in its goals but aspirational and inspirational in its broad strokes
Qiao, Kristoffersson and Randrup (2018)	✓ Unclear leadership and responsibilities, lack of funding, and cost data on management solutions
	✓ Lack of space and knowledge, uniform guidelines, and stakeholder participation

forward-looking and seeks to identify actions for the future, under some circumstances, it may become outdated in less than the range specified by the state and may be unable to guide urban development effectively (Qian, 2013). Therefore, it is necessary to assess the degree of conformity to determine not only the relationship among urban planning theory, practice, and outcomes but also the effectiveness of the existing planning system in controlling urban development (Mabaso *et al.*, 2015; Loh, 2011).

In Iran, the provision of master and detailed plans dated back to the middle of the 1960s and 1970s respectively. Fig. 1 illustrates the process of preparing and approving a master plan in Iran. Since 1999, a total of 304 comprehensive plans have been applied to Iran's cities; however, evidence showed that most of them encountered many problems, particularly in the implementation of the plans because their basic cognition originated from the other countries' patterns and experiences (Rasoolimanesh, Jaafar and Badarulzaman, 2013; Varesi, Ghanbari and Poorghayoomi, 2013). Moreover, their provision process is based on Logical Positivism, which means Survey, Analysis, and Plan, and it is prepared according to the identical process for all cities (Vahidi Borji, Nourian, and Azizi, 2016). As a result, this research paper aims to examine the non-conformity between the proposed master plan to the existing situation quantitatively in Mashhad (Iran). Most researchers found a lack of conformance by comparing planned circumstances with the actual status quo and concluded that there was a failure of spatial and urban planning (Table 1). Consequently, the criteria were gathered by giving out questionnaires and consulting the experts and

urban professors and were categorized into two classes namely demography and spatiality (Table 2). This paper not only measures the degree to which the implementation conforms to the master plan but also represents the deviation of set objectives after its approval using the following criteria. The level and degree of conformity were described as low and high, implying a higher alignment between reality and the proposed plan and vice versa. In other words, high conformity means what has been proposed in the master plan can be seen in the status quo. Since the latest statistical report of Mashhad city was published by the Deputy of Human Capital Planning and Development of Mashhad Municipality in 2021, in this research paper, the current situation refers to the data and information in 2021.

MATERIALS AND METHODS

In terms of context, this research paper is descriptive and analytical, with a quantitative research methodology. Moreover, owing to the objective of this paper, the approach of planning evaluation is post-implementation evaluation. In this type of assessment, the study of the master plan is of paramount importance. In other words, the grasp of proposals and set goals suggested by the master plan is required to measure the degree of conformity. Because there is no identified official list of criteria for evaluating urban development plans, the Delphi technique was employed to set the criteria. The object of the Delphi method is to obtain the most reliable consensus of a group of experts' opinions through a series of intensive questionnaires interspersed with controlled opinion feedback (Dalkey and Helmer, 1963). Therefore, ten questionnaires were distributed

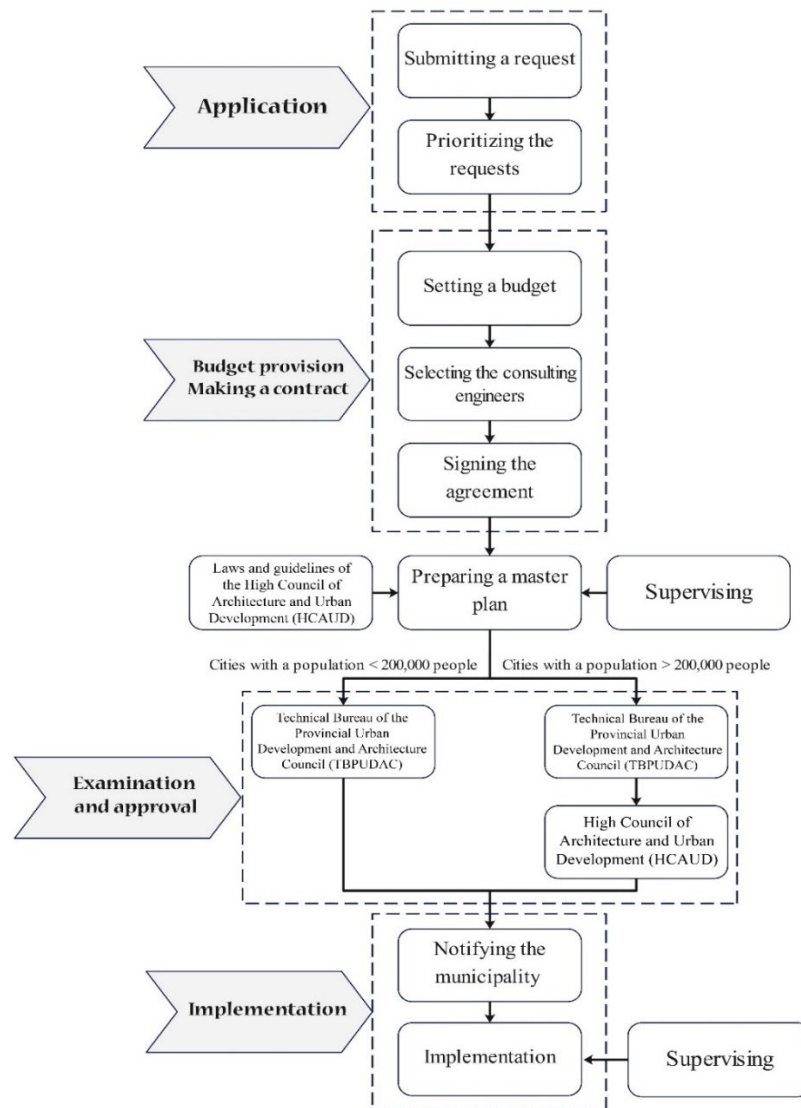


Fig. 1: The hierarchy of preparing a master plan in Iran
(Moradi Masihi and Khalaj, 2010; Rasoolimanesh, Jaafar and Badarulzaman, 2013).

among academic and professional individuals with backgrounds in master planning and implementation. Their feedback and viewpoints were collected. Table 2 is the outcome of the Delphi technique. Hence, generally, the assessment of the criteria was conducted based on the city's master plan, and a comparison between the present GIS data and the suggested maps of the master plan. Furthermore, in some cases, to measure the degree of conformances, some quantitative models were applied. For instance,

the geographical direction of urban development was depicted by the Mean Center and the Standard Deviational Ellipse. The Mean Center, which creates a feature class containing a single feature representing the centrality of a geographic dataset of population, calculates the geographic center for a set of features and it can also be weighted by a numeric field. The Standard Deviational Ellipse also called directional distribution creates an ellipse that measures the directional trend in the data along with the central

Table 2: Criteria measuring the conformance of master plans

Category	Criteria
Demography	Population
	Geographical direction of development
	Land use and per capita
Spatiality	Sprawl built-up areas
	Street network

tendency and dispersion (Pimpler, 2017). On the subject of land use, Mashhad's master plan offered a proposal land use map and each parcel is assigned a land use type, the per capita and area of which in two periods (status quo and proposal) were gathered and compared. The ratio of the developed area conforming to the plan to the total planned area was calculated by the Planning Implementation Rate (Long, Gu, and Han, 2012).

RESULTS AND DISCUSSION

This paper assesses Mashhad's status quo in terms of conformity to its last master plan which was examined and approved by the High Council of Architecture and Urban Development. Fig. 2 represents Mashhad's geographical location. Based on the latest report of the official Population and Housing Census in 2016, Mashhad, the second greatest metropolis of Iran, had a population of 3001184 people (Management and Planning Organization of Khorasan Razavi Province, 2017). As latest reported by the Deputy of Human Capital Planning and Development of Mashhad Municipality (2021), the population equaled 3062242 people, an area of 307.9 square kilometers (Km²), and a population density of 9945.5 people per square kilometer. So, in this research paper, the status quo refers to the data and information in 2021. Mashhad has been described as a regional city with a national function (Farnahad Consulting Engineers, 2011). Hitherto, three master plans have been offered for the city. The last master plan named "Development and Construction Project (master plan) of Mashhad Metropolis" was provided by the General Office of Urban Plans and Studies of Mashhad and approved in 2016. This master plan depicts the future of Mashhad city with a time horizon of ten years in 2029.

Population

As reported by Mashhad's master plan, three

alternatives for population estimation were contemplated and introduced by 2029 which were based on the immigration rate. The first alternative represented the stable immigration rate calculated between 1986 and 2006 and generalized to the future population estimation. The second alternative assumed that the immigration rate had a slowly decreasing trend which stopped at the end of the period, as a result, the population estimation will be 3666300 people in 2029. The population estimation of the third alternative was computed based on the meaning of previous alternatives. Fig. 3 illustrates the regression charts of the population in Mashhad. Among the following suggested alternatives, the first shows the highest population for the city of Mashhad. In terms of conformity, the second alternative is close to the population of the status quo and has a high conformance rate (83.52%). The lowest conformance belongs to the first alternative with a demographic difference of 889158 people (Table 3).

Urban development direction (Geographical direction of development)

Population distribution across the city reveals the direction in which the city develops. To illustrate that, the Mean Centre and the Standard Deviation Ellipse were utilized. The Mean Center (Eq. 1), where n is defined as the total number of census blocks, and x_i , and y_i are the coordinates of the feature named i (Asgari, 2011). Mashhad's census blokes in 2006 and 2021 were used to have a better grasp of development direction. By using the formula, the final output will be a point feature layer representing the center of population concentration. Any changes in the Mean Center show the direction in which the population is accommodated resulting in general urban development direction. In addition, the Standard Deviation Ellipse (Eq. 2) where x_i and y_i are the coordinates of the feature, n is the total number of census blocks and $\bar{X}$ and $\bar{Y}$ represent

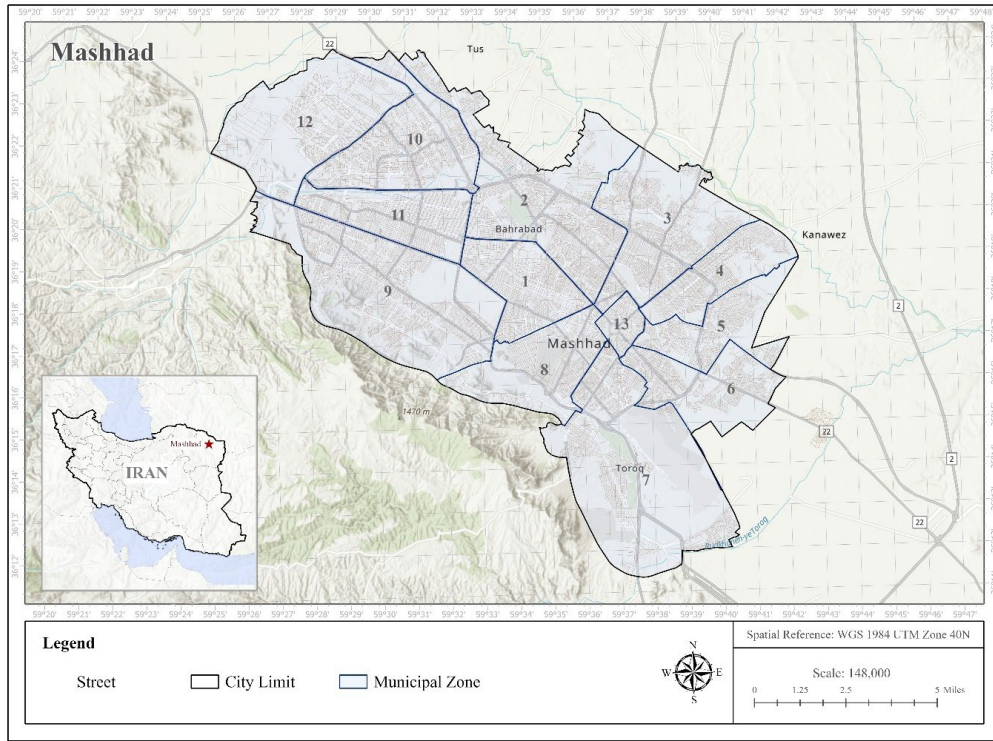


Fig. 2: The general position and geographical location of the study area

Table 3: Evaluating the conformance of the current population with the proposed values

Time	Mashhad	
	Population	Conformance (%)
Status Quo	3062242	-
Proposed Values (Master plan)	(1) 3951400	77.49 %
	(2) 3666300	83.52 %
	(3) 3808800	80.39 %

the Mean Center of the feature (Jahanbani and Lashkari, 2022).

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}, \quad \bar{Y} = \frac{\sum_{i=1}^n Y_i}{n} \quad (1)$$

$$SDE_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}}, \quad SDE_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{Y})^2}{n}} \quad (2)$$

According to Mashhad's master plan, considering the natural barriers such as plenty of agricultural lands in the east, southern, and southwestern

heights, Kashafrud River, and Binaloud County in the north and west sequentially, the northwest zone was identified as the area for new urban development which has vast areas of vacant lots. Similar to Mashhad city's mean population centers, which moved to the northwest, the directional distribution of population is heading to the northwest which conforms to the master plan's proposed way for future urban development. Hence, in terms of the direction of urban development, it seems that Mashhad's current path of development is compatible with the proposed direction (Fig. 4).

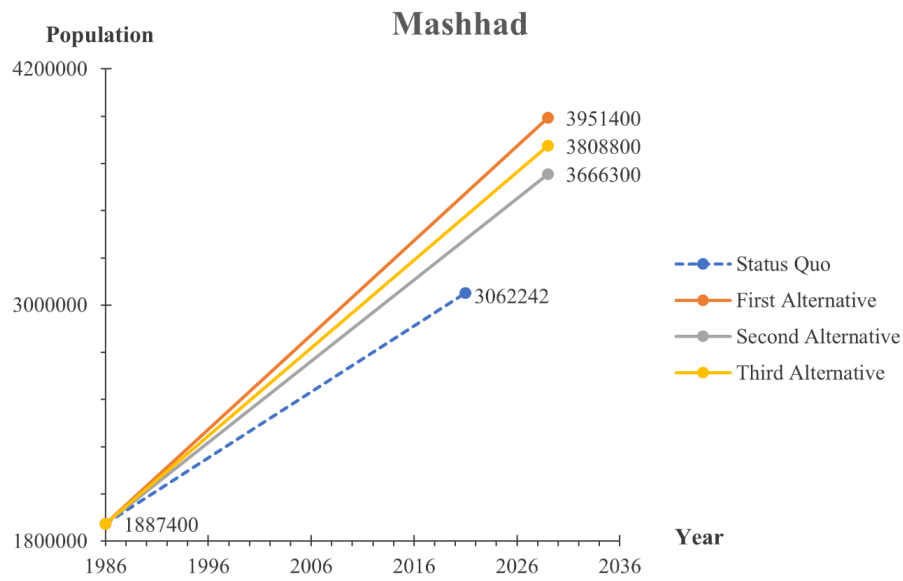


Fig. 3: The regression chart of the population in Mashhad

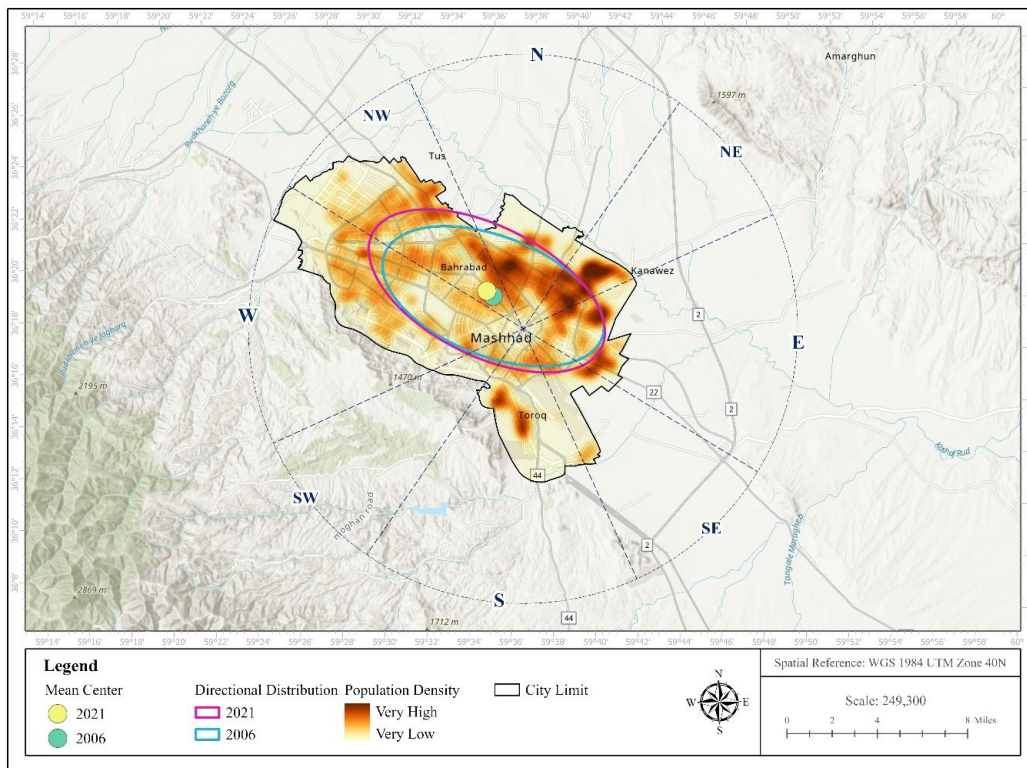


Fig. 4: Urban development direction in Mashhad

Land use and per capita

Broadly speaking, the total area of land use should cover 282.776 km² (roughly 91% of the city's area) in 2029. At the moment (based on the data from 2021), land use area occupies almost 77% of the urban area so considering the vacant lots in the city, there is still room for improvement. Residential use has the highest area (73.012 km²) and the per capita of 24.33 m² per person consisting of approximately 31% of the total land use area currently. The proposed area of the residential part should be 179.189 km² in 2029 which is about 39% higher than the current area of the residential use. Afterward, undesignated use and

agriculture and gardens with areas of 51.258 and 19.767 km² have the highest area respectively (Table 4). Undesignated uses are referred to uses that are not identified and classified; so, there is a lack of precise data about these classes and they were put aside for a non-conformity analysis. In addition, two types of land use in the city were not considered and devised in the proposed land use plan and vice versa named military and mixed uses. Essentially, military and industrial uses are considered incompatible with the rest. As a solution, the proposed plan halved the area of industrial use and omitted the military use within the city's boundary. In other words, the military use

Table 4: Comparing the related values of land use in two different periods in Mashhad

Type of Land Use	Current Values			Proposed Values		
	Area (Km ²)	Percent	Per Capita (m ² /person)	Area (Km ²)	Percent	Per Capita (m ² /person)
Accommodation Center	0.586	0.25	0.20	1.290	0.46	0.35
Administrative and Police	4.089	1.72	1.36	3.353	1.19	0.91
Agriculture and Garden	19.767	8.29	6.59	13.571	4.80	3.70
Commercial	6.148	2.58	2.05	9.216	3.26	2.51
Cultural	0.228	0.10	0.08	2.547	0.90	0.69
Education	3.560	1.49	1.19	0.110	0.04	0.03
Education, Research, and Technology	9.458	3.97	3.15	11.417	4.04	3.11
Suburban Area	-	-	-	3.432	1.21	0.94
Historical Heritage	0.104	0.04	0.03	0.049	0.02	0.01
Industry	5.508	2.31	1.84	3.191	1.13	0.87
Military	11.612	4.87	3.87	-	-	-
Mixed Uses	2.484	1.04	0.83	-	-	-
Park and Green Space	13.073	5.48	4.36	22.644	8.01	6.18
Recreation and Tourism	-	-	-	7.044	2.49	1.92
Religious	0.652	0.27	0.22	0.496	0.18	0.14
Residential	73.012	30.63	24.33	179.189	63.37	48.87
Sports Center	1.521	0.64	0.51	1.593	0.56	0.43
Transportation and Storage	13.297	5.58	4.43	14.747	5.22	4.02
Treatment Center	1.257	0.53	0.42	3.585	1.27	0.98
Urban Utilities	0.908	0.38	0.30	0.913	0.32	0.25
Urban Facilities	1.357	0.57	0.45	0.748	0.26	0.20
Undesignated	51.258	21.50	17.08	-	-	-
No Data	18.503	7.76	6.17	3.642	1.29	0.99
Sum	238.383	100.00	79.43	282.776	100.00	77.13

Table 5: The percentage of conforming and non-conforming uses in Mashhad

Type	Area (Km ²)	Percent
Conforming Use	109.57	47.00
Non-Conforming Use	55.48	23.80
Undesignated	49.74	21.33
No Data	18.33	7.86
Sum	233.12	100.00

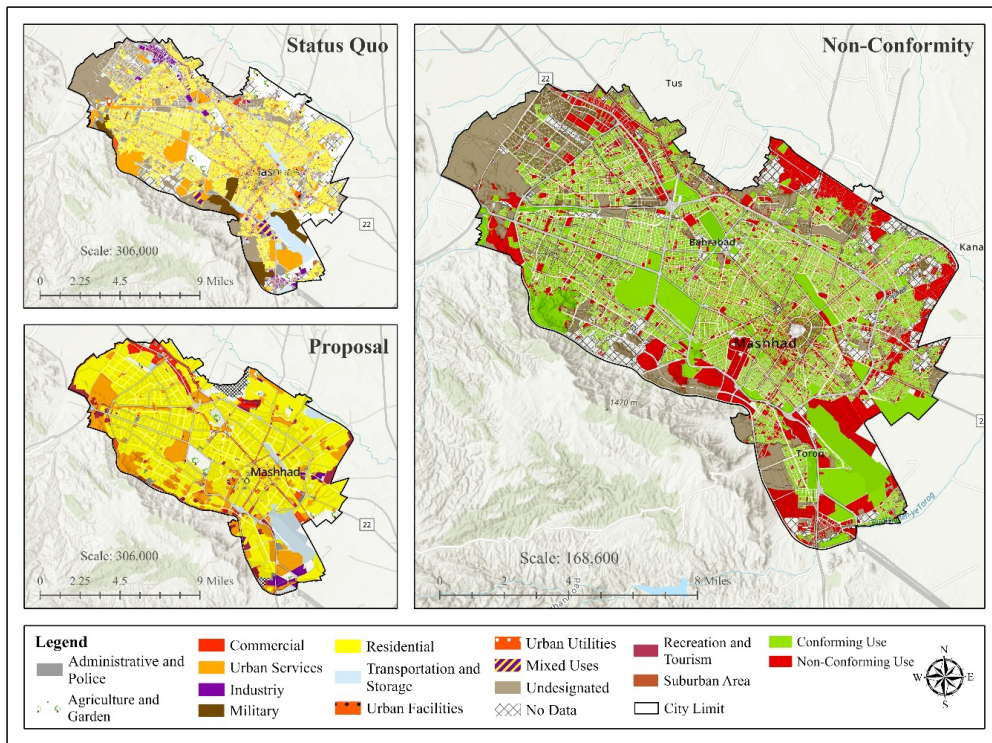


Fig. 5: The conformity and non-conformity between the status quo layer and the predicted one

owns about 5% of the total land uses, placing the south and southeast, so their positions must change and transfer to the outside city. Instead, the majority of its area was assigned to transportation and storage (3.22 km²), and residential (3.01 km²) successively. Between the Payambar Azam expressway and Tus Boulevard is an agglomeration of industrial uses. As reported by Mashhad's master plan, the suggested area was reduced by half and must reach 1.13 km². As substitutes, residential and commercial must cover the diminished parts. Land use per capita has a reverse

relationship with the city's population. There is a subtle distinction between land use per capita value in the status quo and the proposed plan. At this time, the land use per capita stands at 79.43 m² per person which is higher than the proposed value. Indeed, the proposed value should be 77.13 m² per person by 2029 which is a narrow difference from the existing value. Because the speed of urban sprawl is higher than the speed of population growth in Mashhad, land use per capita, as it stands, is expected to rise and exceed the set value till 2029. Moreover, the per

capita of the few land uses including accommodation centers, commercial, cultural, park and green spaces, residential, and treatment centers have a low level of conformity, since the current values are lower than the suggested ones of the master plan. The level of conformity not only represents to what degree the governments obey and act on master plans but also reveals the effectiveness of land use plans.

To determine areas of non-conformance, each land use in the current land-use layer was juxtaposed with its corresponding one in the proposed land-use layer. As a result, a new vector layer illustrating all differences (non-conforming uses) and analogies (conforming uses) was created. Moreover, the parcels that their land uses are hitherto undesignated, and there is no recorded data for them were specified as “undesigned” and “no data” successively. By and large, the majority of the non-conforming areas are situated in the south-to-east part, the northwest and north segments of the city also, there are some dispersed non-conformities across the city (Fig. 5). The areas of non-conformity come 55.48 km² equaling

approximately 24% of the total area (Table 5).

Fig. 6 Represents the non-conformity in Mashhad’s neighborhoods and municipal zones. In this map, the areas of non-conforming uses were added together in two separate scales. The left map illustrates the non-conformity in Mashhad’s neighborhoods. Four neighborhoods called Abshar, Airport, Abouzar, and Ismail Abad situated in the southwest, south, and north respectively have the highest area of non-conformance ranging from 1.83 to 5.06 km². Furthermore, the right picture demonstrates the non-conformity in municipal zones. As represented in Fig. 6, zone 7 including the neighborhoods of Airport and Abouzar gained the highest rank in terms of non-conformance. The uses such as military and industry with an area of 5.23 and 1.50 km² respectively were the cause of the majority of non-conforming uses due to being incompatible uses; they were located out of the city boundary in the proposed land use plan. Zones 8, 9, 2, and 3 owned the second place with an area between 4.35 and 6.41 km².

To compute Planning Implementation Rate (R_p)

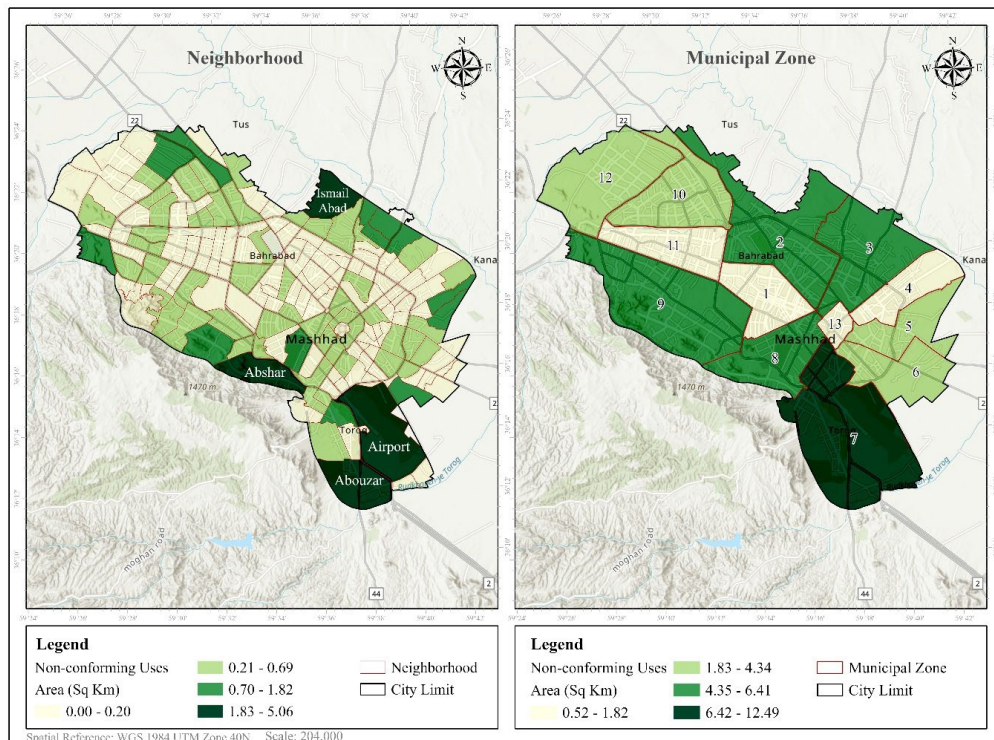


Fig. 6: The different scales of the non-conformity of land uses in Mashhad

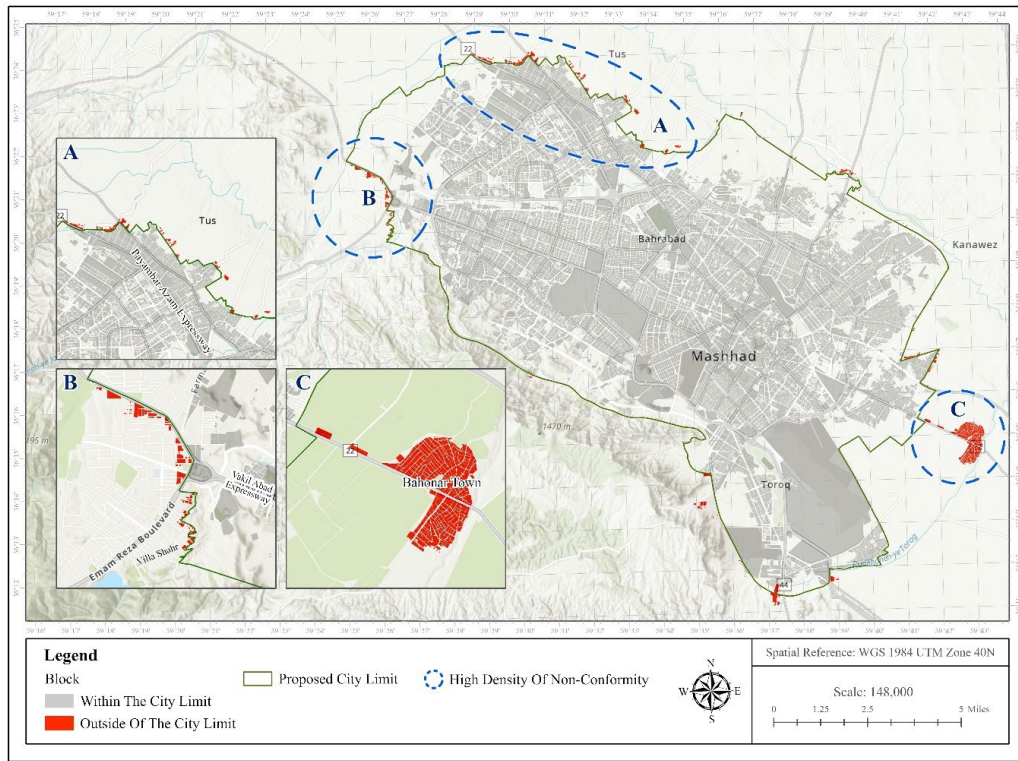


Fig. 7: The sprawl construction outside of the city's proposed limit

(Eq. 3), indicating the ratio of the developed area conforming to the plan to the total planned area, all land uses fell into two categories namely urban forms (residential, commercial, industrial, green space and park, etc.) and non-urban forms (farmland, Garden and agricultural land) where a_{11} denotes that not only the current land uses but also the planned ones are urban form, a_{10} indicates that the current urban forms are non-urban and the planned urban forms are urban (Long, Gu and Han, 2012).

$$R_p = \frac{a_{11}}{a_{10} + a_{11}} * 100 \quad (3)$$

An area of 193.036 km² is that urban forms both in status quo and proposed land use plans (a_{11}) and a_{10} stands at 10.792 km². To put the values of the variable into the related formula, the Planning Implementation Rate equals 94.70%. In other words, 94.70% of the developed area was implemented

following the master plan showing signs of high conformity.

Sprawl built-up areas

Because Mashhad faces a physical sprawl pattern, a bundle of effort has been made to control the city limit strictly and forbid outside construction. As a result, there is no striking difference between the proposed and existing city limits, and they largely overlap with each other. The constructed areas that exceeded the proposed city limit show not only non-conformity but also ineffective boundary control. Fig. 7 indicates the non-conforming blocks outside of the city's set boundary. Specifically, three areas with high density located in the west, northwest, and east (Bakhonar town) have the highest level of mismatch. Up to now, the sprawl built-up blocks come to a total number of 2.38 Km². Consequently, disseminated construction in the suburbs comes into conflict with the suggested limit and represents that the set limit was only on paper and not implemented in the urban

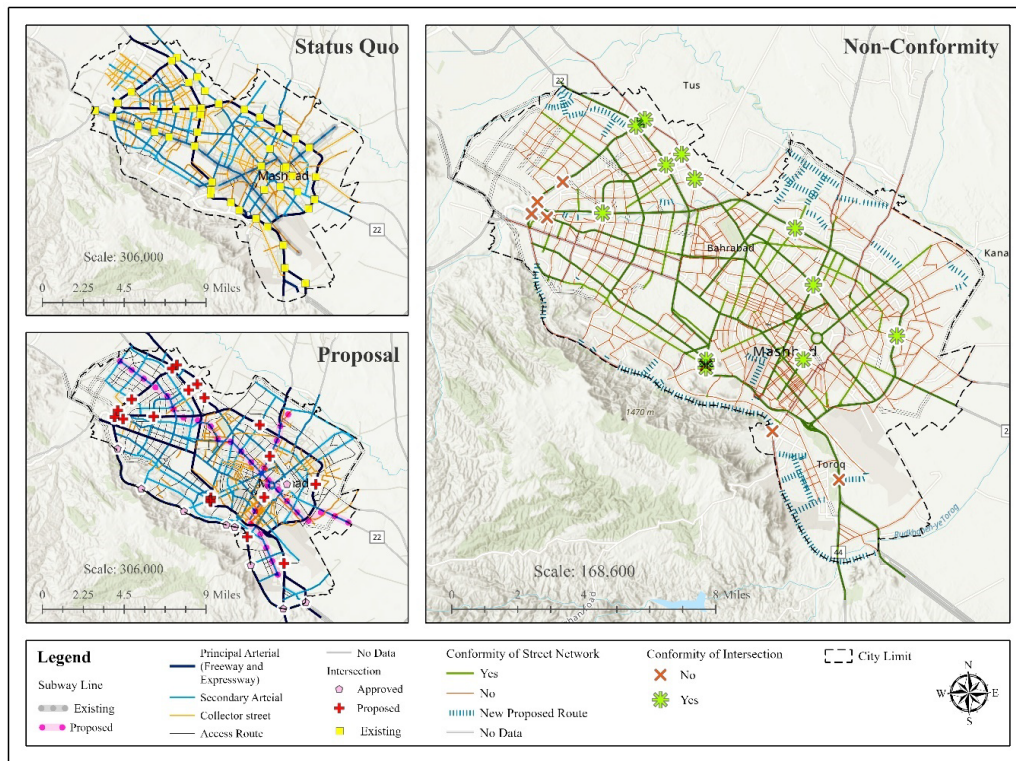


Fig. 8: The non-conformity of the urban streets between the status quo and the master plan

reality which fuels much more urban sprawl further down the road.

Street network

The principal arterials have a total length of 76.5 km and a width of 100 m encompassing the primary core of the city also known as the main region having a star-shaped form, the middle region and zone 10. The proposed length for the principal arterials should be 128 km by 2029 connecting more segments of the city. Moreover, the sum of lengths of secondary arterials, collector streets, and access routes equal 187, 222, and 28 km successively which should reach about 268, 135, and 266 km sequentially for the next six years. Generally speaking, the routes, which are not following the status quo, have a total length of 488 km which means approximately 58% of the proposal outline of the street network mismatches the existing network. The majority of the non-conformity is associated with secondary arterials. Additionally, the master plan proposed a length of 62 km for the

new routes aligned with the development of the city. These new routes should be built in the north, northwest, and southeast where not only are there plenty of vacant lots but also, they are compatible with the direction of urban development. The total number of existing intersections stood at 46 in 2021. The number of 19 intersections was proposed by the master plan located mainly around the principal arterials of zone 10. Twelve intersections conform to the status quo and the rest (7 intersections) have not been implemented. The rate of non-conformity is 37%, as a result. These non-conformities can be observed in the south of the city as well as the east part of Zone 10. Two subway lines provide services from the south to the west (Line 1) and the northeast to the southwest of the city (Line 2). Two new routes were taken into consideration, designated as the Line 3 and the Line 4. The longer route (Line 3) serves the southeastern and northwestern areas of the city. The shorter route (Line 4) long) serves the northeastern and western segments of the city. Because the

proposed subway routes are in the process of being implemented, it can be concluded the proposals of the master plan correspond to the existing situation (Fig. 8).

Improvements in conformity are not limited to one party; they require multidisciplinary collaboration. For instance, urban planners can engage with various organizations, such as local government, residents, and communities, to understand the residents' needs and the communities' shortages. This action gives them deep insight into the study area they plan for. As a result, they can be more accurate and functional in their suggestions and meet people's needs. It reduces the non-functionality, narrows the non-conformity, and reserves time and funds.

Limitations

The foremost limitation of the study was data availability. The indices could have been broader in different categories, such as income and housing, to see if the reality could meet the master plan suggestions. However, while the master plan data were available, finding the current data was challenging. While this study provides insight into the conformity of Mashhad's master plan with its status quo, future research can explore different aspects of the master plan and compare it to reality; this helps to understand in which aspects of conformity and non-conformity are significant. Also, future studies can cover multiple urban sites to see if there are any patterns and common characteristics among them; the problem of non-conformity can be addressed through a united approach, or there should be unique approaches and policies per site. Additionally, the comparison can be beneficial to see where the percentage of conformity is high and how those cities successfully rival the other cities.

CONCLUSION

Mashhad's third master plan provides a framework for future developments. A series of indicators and regulations were appointed and defined in the master plan. To assess its efficacy, the master plan was monitored to identify the degree of conformity and implementation and shortcomings leading to suggestions for plan adjustments. A set of indices were used for evaluation pooled out through the Delphi technique which encompass two facets of the master plan (demography and spatiality) using

the integration of GIS techniques with quantitative models and analyses. On the subject of demography, the master plan represented three alternatives. After the alternatives had been evaluated, the second one with a conformance rate of 83.52% had the highest analogy to the existing urban population. In this alternative, it was assumed that the immigration rate had a slowly decreasing trend which stopped at the end of the period, as a result, the population estimation should be 3666300 people in 2029. At the moment, the population stands at 3062242 people with a narrow difference of 604058 people from the set goal. Spatial-wise features namely the geographical direction of development, land use and per capita, sprawl built-up areas, and street network were measured. Utilizing two models called Mean Center and the Standard Deviation Ellipse, the center of Mashhad's population concentration and its direction were ascertained (northwest) showing exact conformance to the proposed direction by the master plan. The next evaluated indicator was the land use plan and its per capita, the findings revealed that the per capita of the few land uses including accommodation centers, commercial, cultural, park and green spaces, residential, and treatment centers gained a low level of conformity. Indeed, their assigned area and per capita were lower than the established values. On the other hand, the per capita and area of the other land uses were higher than the proposed values. In addition, the southeast part, the north and northwest segments of the city had the majority of the non-conforming areas with an area of 55.48 km² (about 24% of the total area). To put it differently, 24% of the current land uses contradict the proposed ones. To measure the degree of implementation following the master plan, the Planning Implementation Rate was calculated; as a result, 94.7% of the developed area was implemented as urban forms that were compatible with the planned document. Indeed, the rate centers on the constructed lands and examines what percentage of the lands are developed and enforced in the form of urban forms. Therefore 94.7% represented high conformity of implementation and the remainder of 5.30 % was not enforced according to the master plan. Furthermore, uncontrolled residential expansion in Mashhad's suburban area (in particular west, northwest, and Bahaonar town) illustrates an error in implementation. The sprawl built-up blocks occupied an area of 2.38 Km² which

contradicts the set boundary by the master plan. Considering the street network, the non-conformity rate stood at 58% and the collector streets formed the majority of them, also 62 km of the new proposed routes were not constructed yet. However, it appears that the municipality had a better performance in implementing the intersection according to the master plan. To sum it up, the master plan had a good performance in forecasting Mashhad's population and the development direction in 2029. On the other hand, Mashhad's municipality (the organization that must implement the proposals of the master plan) had a poor performance in regulating the city's boundary and construction of the new routes but it acted almost well on land use implementation (conforming rate of 47%). The non-conforming uses had a percentage of 23.80. There are several rationales why the current land use plan differs from the approved and suggested one. Sometimes the proposed land use plan cannot meet the citizens' needs resulting in the inefficiency of the plan also, the administrative system and paperwork become super sophisticated in some cases, and people's unhealthy economic situation and private interests of some organizations can be the other factors which not only alter the approved plan but also stray from the proposals of the master plan. In terms of the level of realization, Mashhad's master plan is placed in the middle up to adverse levels, and the majority of the non-conformities were caused by the implementation process. Generally, conformity happens when planners consider a city's current trends; otherwise, the city responds to its needs independently, leading to results contrary to the suggestions, for instance, marginalization or sprawl outside the recommended areas. As a result, cities are growing super-fast and are constantly evolving. It is unrealistic that a master plan with a long-term perspective, without any continuous assessments, can effectively address every aspect of their growth and solve all their problems. Continuous assessment of the master plan during the implementation to reduce and rectify the errors and verify the correctness of the data plays a crucial role in efficiency improvement. Likewise, it can improve the adverse condition and raise the level and degree of realization. Additionally, the iterative collaborations among the involved organizations lead to a better understanding of the area of study and contribute to effective planning.

AUTHOR CONTRIBUTIONS

M. Jahanbani helped with the research method and performed the conceptualization, software, validation, formal analysis, investigation, resources, data curation, writing the original draft, and visualization. E. Lashkari was the mentor and performed the introduction, literature review, methodology, writing - review and editing, and graphical abstract; helped in conceptualization, formal analysis, and resources.

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CONFLICT OF INTEREST

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

PUBLISHER'S NOTE

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ABBREVIATIONS (NOMENCLATURE)

a_{10}	Current land uses are non-urban and the planned ones are urban
a_{11}	Current land uses and planned ones are an urban form
<i>Eq.</i>	Equation
<i>GIS</i>	Geographic Information Systems
<i>km</i>	Kilometer
Km^2	Square kilometer
<i>m</i>	Meter

m^2	Square meter
n	The total number of census blocks
R_p	Planning Implementation Rate
SDE	Standard Deviatonal Ellipse
x_i	The coordinate of the feature named i across the X-axis
$\bar{X}$	The mean of all X
y_i	The coordinate of the feature named i across the Y-axis
$\bar{Y}$	The mean of all Y

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ORIGINAL RESEARCH PAPER

Structural equation modeling of collective decision-making's impact on group cohesion

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ABSTRACT

BACKGROUND AND OBJECTIVES: Cohesion is one of the most important factors in the sustainability of social relationships and organizational success. Evidence shows that many companies and organizations have failed or disappeared due to a lack of cohesion among their employees. For this reason, it is important to identify the factors that affect the convergence of individuals and strengthen the cohesion among them. The primary focus of this study revolves around the question of whether group cohesion can be enhanced through the utilization of a collective decision-making approach. Collective decision-making is about reaching a single decision by the group members. This research assesses the correlation between common rationality (as a basis for decision-making), collective decision-making, and cohesion.

METHODS: To achieve the research purpose, a conceptual model is designed using the research background and interviews with experts, and then the structural equation method is used to achieve the research objectives, and Smart PLS 2.0 software is used to analyze the data. In this study, the concept of common rationality is examined as an exogenous factor, while cohesion is viewed as an endogenous factor, and collective decision-making is regarded as a mediating factor. To analyze the interplay among these factors, it is essential to assess the P-value, T-value, and regression coefficient, which are determined using structural equation modeling.

FINDINGS: The goodness of fit is employed to assess the overall model fit, which is obtained as 0.469, and this criterion indicates that the overall model fit of the research model is appropriate. The regression coefficient between the variables "common rationality → collective decision-making" is 0.668, and between the variables, "collective decision-making → cohesion" is 0.550, which shows a significant positive relationship between these variables. However, the regression coefficient between the variables "common rationality → cohesion" is 0.234, which indicates a weak relationship between these two variables. The findings suggest that common rationality has an impact on group cohesion by way of the intermediary factor of collective decision-making.

CONCLUSION: Although common rationality is a significant asset for an organization and society, managers and governors who want to use it to increase cohesion must activate it through collective decision-making. By engaging diverse perspectives, enhancing communication, and developing collective skills, they can create environments where shared understanding and cohesive action thrive. This study can encourage managers and governors to use the collective decision-making method in their choices.

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INTRODUCTION

Collective decision-making, a subset of collective behavior, addresses arriving at a specific decision within a group (Bosel *et al.*, 2017; Makinson *et al.*, 2017). Collectives vary in structure, involving individuals, groups, and even social networks (Dionne *et al.*, 2019). A collective decision-making process involves multiple individuals, each with their perceptions, attitudes, motivations, and personalities, recognizing a common problem and striving for a collective decision. Groups may interact simultaneously or make individual decisions before discussing outcomes collectively (Bui, 1987). Essentially, collective decision-making entails two or more actors aiming to address a specific issue and coordinate toward a shared goal, expressing preferences and beliefs to reach a unified decision (Marks *et al.*, 2019). Coherence becomes relevant when individuals or groups encounter challenges in executing actions. While opinions vary on the impact of collective decision-making on cohesion, the presence of dualities among team members can disrupt cohesion (Lloyd *et al.*, 2013). Social cohesion, however, addresses various social issues like conflicts and irresponsibility (Fu *et al.*, 2020; Sueur *et al.*, 2011). Despite the broad applications of collective decision-making and its impact on group cohesion, existing research lacks clarity on how participation in these processes is constructed and implemented effectively. Previous studies have highlighted the benefits of collective decision-making and group cohesion (Mann, 2018; Dionne *et al.*, 2019; Ehteshami & Sarfarazi, 2012), but they do not comprehensively understand the mechanisms and pathways for fostering participation. This study aims to bridge this gap by holistically identifying and evaluating pathways for fostering participation to enhance cohesion and related indicators within organizations. Focusing on the construction and implementation processes of participation in collective decision-making, this research seeks to provide clear and actionable insights for managers and governors to improve organizational and societal outcomes. It stands as a crucial parameter in bolstering cohesion, with numerous positive effects on managerial and staff performance, such as fostering alliances, enhancing information dissemination, increasing awareness and knowledge, boosting motivation, harnessing collective wisdom, fostering staff commitment,

minimizing errors, improving decision accuracy, enhancing collective intelligence, and averting instability and intractability (Carbone & Giannoccaro, 2015; McHugh *et al.*, 2016; Zafeiris *et al.*, 2017; Bosel *et al.*, 2017; Khaluf *et al.*, 2019; Fu *et al.*, 2020). The notion of achieving common rationality emerges as a cornerstone of collective decision-making, uniting individuals with diverse attitudes and opinions (Bisset *et al.*, 2020; Birkeland *et al.*, 2020; S. Yilmaz & Kafadar, 2020). Common rationality denotes the extent to which a group shares understanding and resolutions, fostering common thinking and goals within the community (Tongo, 2015; Palmiero *et al.*, 2020). Common rationality thus becomes a pivotal element influencing collective decision-making. To explore these concepts further, the Structural Equation Model (SEM) identifies key indicators of common rationality, collective decision-making, and cohesion, examining their interrelationships. This study investigates the correlation between shared rationality, group decision-making, and cohesion, as elucidated in the preceding explanation. The research was carried out within Iran's governmental institutions in 2023.

Literature review

This literature review provides a structured theoretical framework to understand the interrelations among common rationality, collective decision-making, and cohesion. By delineating the foundational theories and key concepts in each area, this review aims to clarify how these elements enhance organizational and societal outcomes. This literature review has outlined the theoretical underpinnings of common rationality, collective decision-making, and cohesion. By understanding these foundational theories and their interconnections, this study aims to provide a clearer framework for enhancing organizational and societal outcomes through improved participation and cohesion in collective decision-making.

Common rationality

Rationality encompasses a range of abstract characteristics within individual attitudes, including beliefs, values, preferences, desires, and intentions. It is highly contingent on individual attitudes, and any shifts in beliefs, preferences, or intentions inevitably lead to changes in rationality. Individuals often employ

rationality in analyzing their surroundings and making decisions based on reasoned arguments (Jagau & Perea, 2022; Perea, 2022). Max Weber introduced the rationality principle as a methodological guideline, asserting that social scientists can understand social actions and motivations by understanding their reasons. This principle, rooted in Weberian *Verstehen* sociology, posits that the conduct of a social actor is comprehensible, thereby facilitating understanding among society members (Rusu, 2013). The notion of rationality extends universally across human cultures, with common rationality serving as a bridge for individuals with diverse cultural backgrounds and attitudes to understand one another (Rusu, 2013). Common rationality holds significance not only in game theory but also in various economic contexts. In game theory, the rationality of players in strategic interactions forms the foundation for many games' theoretical concepts (Mounir et al., 2018). Likewise, in economics and business studies, common rationality fosters a shared understanding and collective goals (Tongo, 2015). Mainstream industrial organization models presume common rationality, wherein competing entities make decisions based on the assumption of rationality among all parties involved. This principle extends to political economy, where politicians, assuming common rationality, vie for voter support (Elio, 2002).

Collective decision-making

Individuals encounter collective decision-making scenarios regularly in their daily lives (Veen, 2011). This practice spans various fields, including behavioral and brain sciences, management, economics, and artificial intelligence, with a specific emphasis on identifying strategies that empower decision-makers to select the most advantageous option among several alternatives (Hasegawa et al., 2017). Groups have a fundamental goal of formulating efficient resolutions to the intricate challenges they encounter. This facet of social group behavior holds significant relevance, as the concept of "collective wisdom" has the potential to outshine individual behavior in terms of quality (Zafeiris et al., 2017). Given the swift changes in the environment, it's impractical for a decision-maker to possess a comprehensive mastery of all sciences, issues, and technologies necessary to find the exploit of a situation fully or optimal solution. However, few individuals possess such omniscience

or expertise covering all requisite fields within the scope of their managerial responsibilities. Hence, collective decision-making emerges as a valuable tool to aid in finding optimal solutions (Akram et al., 2023). The contemporary landscape of societal transformation mandates the active engagement of both managers and staff in the decision-making process and subsequent implementation procedures. Without their involvement, achieving an optimal decision becomes unattainable (Prigozhin, 1991). Enhancing collective decision-making is imperative, given the expected variance in the precision of individual decision-making (Bosel et al., 2017). The examination of collective decision-making holds great significance for various group or participatory systems, particularly in conjunction with the progress of electronic communications, the internet, information technology, and knowledge-based economics (Sinnaiah et al., 2023; Wu et al., 2017). In a system of collective decision-making, several key components contribute to its functionality:

(1) *The circumstances, objectives, convictions, or inclinations of individuals,*

(2) *The capacity of individuals to impact the stances, inclinations, and opinions of others or the outcome of the ultimate decision,*

(3) *Social interactions and collectives that emerge from these interactions,*

(4) *the wider framework in which the group functions* (Zellner et al., 2014; Mirbagheri et al., 2024). Collective decision-making processes are often shaped by social feedback networks within the group (Planas-Sitja et al., 2015). Throughout these processes, individuals typically share their opinions while adhering to certain limitations and preferences, ultimately leading to a consensus decision (Rossi, 2014). Furthermore, proficient personnel who may not have direct involvement in the decision-making process frequently contribute on an equitable level, enhancing the decision-making procedure with their specialized knowledge (Prigozhin, 1991). Khaluf et al., (2019) analyze the intricate relationship between individual (microscopic) and system-level (macroscopic) components in collective decision-making. They underscore the importance of two critical pieces of information that the system must acquire: (1) stimuli, and (2) a set of choices (options) accessible for a specific decision. The outcome of the decision-making process is shaped by various

characteristics of stimuli and options, including their quantity and distribution. Effective communication and conducive conditions within groups can expedite the achievement of consensus at the group level. Additionally, the conduct of group members plays a pivotal role in fostering collective decision-making (Ward *et al.*, 2011). In situations where a collective decision does not come to fruition, individuals involved in a 'group issue' should partake in bargaining or negotiation until a consensus is achieved (Bui, 1987).

Cohesion

Coherence means bringing together various elements in an orderly manner to form a collection. Coherence or correlation means individuals entering a social environment and belonging to the frameworks, constructions, and social conditions of that environment. From the content aspect, cohesion is the concept of being absorbed in national values and norms. By absorbing the person in the national environment, the person accepts obligations toward the environment as a related and responsible element (Lanzi, 2011). Cohesion means solidarity and agreement and is considered one of the components of the "theory of agreement", whose function is to connect individuals of a society. According to these definitions, in the case of cohesion, correlation, and agreement, some elements include collective agreement, common norms (including values, custom, and law), common identity, and the institutionalization of norms in institutions that guarantee the survival of a society (Holtug, 2017). Theorizing about cohesion and concepts close to it such as systemic cohesion, social solidarity, social integration, agreement, national unity, national identity, consensus, and most importantly social order, and on the other side concepts such as conflict, fragmented society, hostility, hypocrisy, disorder, and other related concepts have always been of interest to researchers in the fields of social sciences, political sciences, social psychology, management, and public policy (Fonseca *et al.*, 2019). There are two main theoreticians about coherence or correlation from a functionalist perspective, Emile Durkheim and the other is Talcott Parsons, who initially studied within the framework of structural functionalism and then founded his "school of functionalism", however, he was influenced by Durkheim (Parsons, 1985).

According to Durkheim, societies are organized with the human needs of their members and social cohesion is based on it (Lukes, 1969). In the initial stages, individuals come together based on the fact that their lives and ways of life are very similar to each other and their relationship is "mechanical". It means a simple answer to the common conditions of their social life, which is at the level of social awareness. With this explanation, the more individuals need each other increase, the greater the cohesion of society (Durkheim, 2019). Parsons argues that a shared value system provides the necessary preconditions for social cohesion. According to Talcott Parsons, societies are cohesive and interconnected based on four factors: First, values: which determine the goals and guide the behavior of humans and collective sense in the society; Second, norms: they are the rules of behavior and they are the means of achieving values, the legal system is the most important set of norms; Third, roles: they form different structures of society, such as economic, political or religious roles; And fourth, collectivities: they are the institutional set of values, norms, and roles (Parsons & Smelser, 1956).

Conceptual framework

In this section, the conceptual structure of the research is described and the indicators related to it are identified. Several considerations were taken into account when choosing indicators. The focus was on the central theme of the research, which revolves around the examination of collective decision-making and its impact on group cohesion. Variables associated with this core issue were meticulously identified based on existing literature. The aim was to ensure that the selected indicators comprehensively address all crucial aspects of the central research topic, as using inadequate or inaccurate indicators could result in an incomplete portrayal of the subject matter. Moreover, the simplicity and clarity of the indicators were also taken into consideration to facilitate their use and interpretation by other researchers and users. Another key criterion for indicator selection was their measurability and evaluability by researchers. Also, expert opinions played a significant role in identifying indicators, with the final selection being based on a consensus among experts. Subsequently, the validity of these indicators was assessed through factor loading, and those that

were confirmed were deemed as model indicators. In the following, these indicators are explained in three categories: “common rationality”, “collective decision-making” and “coherence”.

Common rationality

Rationality refers to the assortment of justifications that individuals possess for their actions and behaviors. It involves making wise choices based on our beliefs and interests. For a group to make a unified decision within an organization, they must share a common rationality (Zha et al., 2022). However, when it comes to interactive decision-making, where individuals cannot maximize their expected benefits without making assumptions about the behavior of other stakeholders, the concept of rationality may not be easily comprehensible (Colman, 2003). While there are various indicators of common rationality, they are not limited to the following explanations (Mirbagheri et al., 2023).

1. *Common thinking*: Thinking involves the systematic and logical progression of information towards uncovering what is unknown, to identify answers or solutions to problems (Palmiero et al., 2020). Diverse individuals possess distinct emotional and cognitive inputs when making judgments and decisions, which may be linked to their unique thinking styles. Hence, how one thinks has a direct impact on the approach taken towards decision-making (Liang et al., 2021). The absence of a common rationality factor significantly hinders the ability to predict that, despite individual differences, people’s thinking patterns will converge toward a common direction (Burgoyne et al., 2023).

2. *Common goals*: Each decision-maker possesses unique personal goals that reflect their values and level of ambition. As a result of these individual differences, the goals of individuals diverge, leading to varying outcomes in decision-making. This stands in contrast to collective decision-making, where the group strives to reach a consensus. Consequently, the decisions made by different decision-makers often differ from one another (Klein et al., 2022; Bui, 1987). To reach a collective decision, individuals need to find common ground to work towards common goals. The drive for collective decision-making is closely tied to the pursuit of common goals (Tongo, 2015; Zellner et al., 2014; Assuad, 2020).

3. *Common benefits*: The initial step taken by

individuals involves envisioning a concept before evaluating its practicality and advantages, a process commonly referred to as the “conception of benefit”. Individuals come together and perceive themselves as integral components of a collective entity, acknowledging their role as collaborators in reaping the collective’s advantages (Bui, 1987). If an entire entity successfully attains the appropriate collective objectives, it can likewise attain shared advantages (Ekwoaba et al., 2019). Profit corporations have evolved to a stage where their objective extends beyond mere individual profit to encompass the creation of shared value for all stakeholders. This shift in focus is crucial for fostering unity and harmony within the organization (Marchini et al., 2022).

4. *Common interests*: Interest refers to a longing and tendency towards a particular subject. When interest is present in an individual, it motivates them to make a choice or take action. Interest can be defined as the satisfaction and maximization of a characteristic that describes individuals in search of the optimal option (Miceli et al., 2018). After confirming the advantage, individuals develop a keen interest in the outcome, which gives rise to a sentiment known as “enthusiasm” for them. Interest serves as an essential prerequisite for remarkable accomplishments and choices (Elster, 2020). Common interest within a group can effectively minimize their divergence from the established objectives (Havard et al., 2023).

Collective decision making

Decision-making refers to the cognitive process through which an individual selects an option from a range of available choices (Wu et al., 2017). On the other hand, collective decision-making involves a collaborative approach where each person within a group has the opportunity to influence and make decisions regarding their work and group tasks (Xu et al., 2022). It is a situation where multiple actors come together to enhance their position on a specific issue and coordinate their efforts to achieve a common objective (Marks et al., 2019). Throughout this process, the individuals involved strive to articulate their preferences and beliefs regarding the matter at hand to arrive at a unified conclusion (Marks et al., 2019). The collective decision-making process encompasses the active participation of group members in reaching a decision (De Oca et al., 2011).

It involves multiple actors who seek to improve their circumstances and collaborate on a particular issue to achieve their desired outcome (Gerrits & Marks, 2017). Despite various constraints and personal preferences, individuals typically express their opinions regarding a set of potential decisions, ultimately leading to the selection of a single course of action (Rossi, 2014). It is important to note that the indicators of collective decision-making are not limited to the ones briefly explained below (Mirbagheri et al., 2023).

1. *Voting*: Participating in collective decision-making can be achieved through voting. Decision-making bodies typically employ voting as a means of polling and arriving at the appropriate decision (Van Deemen & Rusinowska, 2010). Voting functions as a mechanism for reaching decisions collectively (Cina & Endriss, 2016). It has evolved into the most prevalent formal technique for collective decision-making (Y. Xu, 2019; Wu et al., 2017; McHugh et al., 2016; Iaryczower et al., 2018) that can greatly improve the number of sound decisions (Szapiro & Kacprzyk, 2022).

2. *Information Sharing*: When individuals within a group are given the chance to communicate with one another, they can exchange their unique knowledge and ultimately arrive at a more informed collective decision (Iaryczower et al., 2018). In collective systems, the sharing of information is accomplished through both direct and indirect interactions among the agents involved (Wu et al., 2017; Sueur et al., 2011; Khaluf et al., 2017; Dionne et al., 2019). This process of information sharing not only facilitates the decision-making process within the group but also empowers individuals to actively utilize the shared information, leading to more informed decision-making (Neef et al., 2022).

3. *Meeting*: A group meeting provides an opportunity for individuals in positions of authority to engage in collective discussions regarding a particular matter (Tropman, 2003, 2013; Oliver et al., 2022; Bui, 1987). Organizing a meeting can catalyze increased active participation from members in the decision-making process (Moayerian et al., 2022). These meetings can take place either in person or online. The act of convening a meeting is one of the contributing factors that facilitate the attainment of a specific desired outcome (Adla et al., 2011). The specific outcome of a decision session may involve the number of decisions reached or the duration of the decision-making process (Zeyda et al., 2023).

4. *Consultation*: It is widely recognized that polls and consultations have a considerable influence on decision-makers, and it is undeniable that an individual's decision can be influenced by seeking consultation (Bui, 1987). Acknowledging the significant role of information in decision-making, as consultation changes the amount of information available, it becomes clear that it will impact decision-making in a certain direction. Therefore, consultation leads to a form of collective decision-making, even if the decision-maker is not required to follow the suggestions and opinions of advisors (Mann, 2018). Consultation is a crucial aspect of collective decision-making (Iaryczower et al., 2018).

Cohesion

The general theory of coherence is regarded as the satisfaction of numerous contradictory constraints (Thagard, 2000; L. Yilmaz et al., 2017). The level of cohesion within a collective decision reflects the extent of consensus within the system, specifically the proportion of individuals who appear to be aligned with the majority viewpoint. Coherence is effectively improved by interaction and information sharing (Khaluf et al., 2019). When we no longer have the desire to reconsider moral precepts, principles, and obligations, cohesion is achieved because they have the highest degree of acceptability (L. Yilmaz et al., 2017). Collective decision-making enhances cohesion, enabling the system to function as a unified entity in the face of diverse inputs and stimuli. By relying on shared information and striving for consensus, the collective decision-making process fosters unity and coherence within the system (Khaluf et al., 2019). In the following, the indicators related to coherence are examined.

1. *Trust-building*: Distrust is one of the common and important causes of conflict between members of different collectives. Trust among collective increases when collective members want to have an opportunity to interact with each other, their interaction is positively reciprocal, and as a result, their belief that collective members are trustworthy increases. The facilitation of this process is enhanced when individuals exhibit minimal hostility towards one another, demonstrate adaptability in revising their beliefs based on new information, and display a certain level of reliance on the group as a whole (Herrera & Kydd, 2022; Tyagi et al., 2022). Over time,

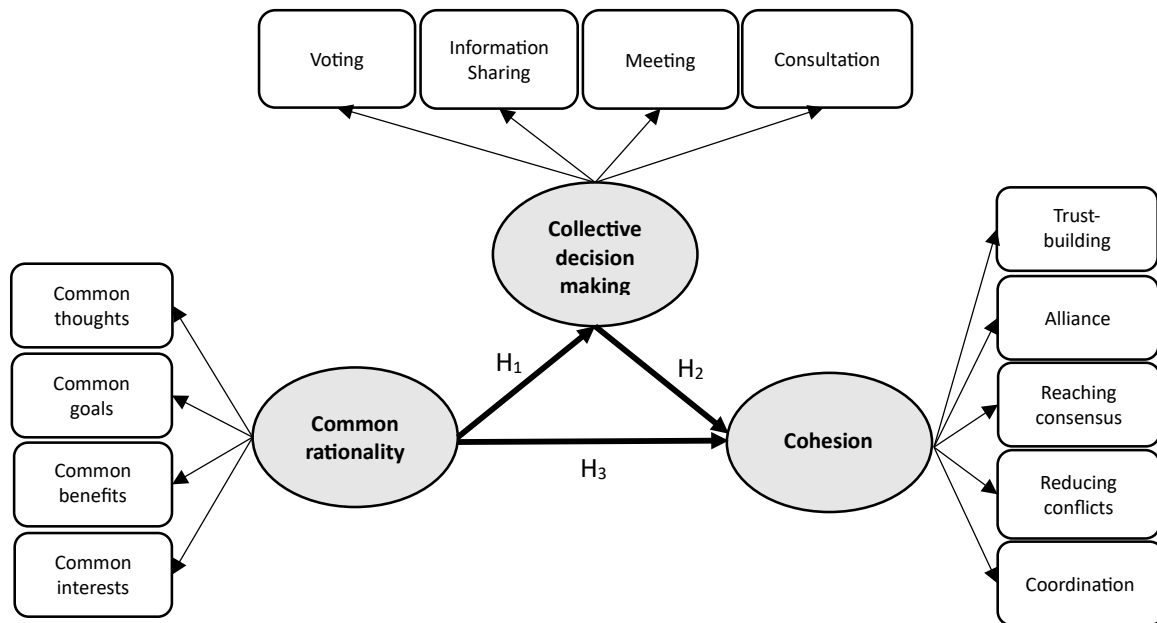


Fig. 1: Proposed research model

members of the collective align with each other and gradually gain trust in each other. In a collective space, decision-makers strive to reach a common decision and share responsibility in a friendly and trusting atmosphere (Bui, 1987).

2. *Alliance*: Alliances are used to coordinate the various activities of stakeholders (Hearld et al., 2013). In a collective decision-making situation, decision-makers make alliances to form an almost homogeneous group and work together to solve a collective problem. It is important to note that charismatic leaders use a collective approach to guide and make an alliance with individuals (Clough et al., 2022; McHugh et al., 2016).

3. *Reaching consensus*: Consensus can increase member participation and increase understanding of the effectiveness of the alliance. Consensus on key issues provides a platform for member mobilization and continued movement (Hearld et al., 2013). In collective decision-making, individuals seek to reach an agreement on a desirable outcome and reach a consensus on this issue (Bosel et al., 2017). Reaching a consensus is the basis for reaching a common decision, and for this reason, it is a very important indicator in collective decision-making (Zhang et al., 2022).

4. *Reducing conflicts*: Conflict and competition

are typical examples of non-cooperative decision-making. When competitors seek to harm their opponents for their benefit, others are confronted with the fact that each competitor is a candidate for the work of others and strives to do better than others. For this reason, conflicts between individuals increase (Bui, 1987), but when cooperation between individuals is established, it causes conflicts between stakeholders to decrease (Watanabel et al., 2022). In this regard, collective decision-making is an effective way to quickly resolve disputes and conflicts between group members (Telem, 1988).

5. *Coordination*: The diverse preferences of group members and their behaviors during collective decision-making create a significant challenge to achieving coordination (Davis et al., 2022). Groups must first coordinate their activity decisions and collectively decide what they want to do if they want to enjoy social benefits and minimize social costs (King & Sueur, 2011). For individuals to reap the rewards of social interaction, they must uphold a certain level of spatial and temporal synchronization in their actions and come to decisions collectively. The closer individuals' experiences and mental models are, the fewer problems there will be, and the greater the difference, the greater the misunderstanding and inconsistency (Sueur et al., 2011).

By examining the definitions outlined for the indicators and delving into the content of pertinent literature sources, alongside seeking guidance from subject matter experts, a conceptual model was formulated utilizing the framework depicted in Fig. 1. This conceptual model determines the three main constructs of collective decision-making, common rationality, and cohesion. Common rationality includes 4 indicators, collective decision-making includes 4 indicators, and cohesion also includes 5 indicators. According to the theoretical framework of the study, three hypotheses have been formulated as outlined below:

H₁: There exists a positive and significant correlation between common rationality and collective decision-making.

H₂: Collective decision-making is positively and significantly associated with cohesion.

H₃: Common rationality has a positive and significant relationship with cohesion.

To measure the relationship between common rationality, collective decision-making, and cohesion, the study survey was conducted in Iran in 2023.

MATERIALS AND METHODS

The research adopts a descriptive and analytical approach, gathering information from library sources for the literature review and employing a questionnaire to investigate sample opinions. Participants knowledgeable about the research subject or possessing field experience are regarded as part of the statistical community. Given the specialized nature of the subject, purposive sampling is conducted, with sample size determined using Cochran's formula as shown in Eq. 1 (Damghanian & Ghanbari Ghaleroudkhani, 2022; Song & Wassell, 2003).

$$n = \frac{\frac{z^2 pq}{d^2}}{1 + \frac{1}{N} \left[\frac{z^2 pq}{d^2} - 1 \right]} \quad (1)$$

n: the value of samples

z: the z-value, extracted from a z-table.

p: the fraction of the population (as a percentage) that displays the attribute

e: desired level of precision, the margin of error

The study adheres to Krejcie and Morgan's (1970) table by distributing the questionnaire to 115 academic and organizational experts. Upon evaluation of the completed questionnaires, 98 were identified as suitable for statistical analysis. The questionnaire consists of three main components with a total of 11 questions to gauge respondents' agreement levels ranging from very low to very high. The questionnaire is designed based on the Likert scale and according to the level of respondents' agreement with the question, it is adjusted from strongly disagree to strongly agree and they are given values from 1 to 5. The number 1 represents "strongly disagree" and the number 5 represents "strongly agree" (Chen et al., 2022). Demographic variables such as age, education level, and gender are taken into account as control variables. Due to the specialization of the research subject, purposive sampling is done. The questionnaire is distributed among managers of Iranian state-run organizations (at different management levels) who are aware of collective decision-making or have experience using it. The demographic information of the statistical sample is shown in Table 1. The results showed that above 90% of the respondents have master's and

Table 1: Descriptive statistics of the sample

		Frequency	Percent	Valid Percent
Gender	Male	62	63.2	63.2
	Female	36	36.7	36.7
Education	Bachelor	7	7.1	7.1
	Master	79	80.6	80.6
	Ph.D.	12	12.2	12.2
	<40	25	25.5	25.5
	40-50	33	33.7	33.7
Age	50-60	29	29.6	29.6
	>60	11	11.2	11.2
	Total	98	100.0	100.0

Table 2: Reliability statistics

Cronbach's Alpha	N of Items
0.808	11

doctorate education, and this issue increased the credibility of the research.

Experts' opinions are used to measure the validity of the questionnaire. Hence, before distributing the questionnaires, the opinions of 17 university professors and experts in the field of collective decision-making are received and the necessary corrections are applied to the questionnaire. The reliability of the questionnaire is also calculated by Cronbach's alpha method (α) based on the formula:

$$\alpha = \left(\frac{n}{n-1} \right) \left(\frac{S_t^2 - \sum_{i=1}^n S_i^2}{S_t^2} \right). \text{ In this formula, } S_t \text{ is the}$$

standard deviation of the entire questionnaire, S_i is the standard deviation of the i th question, and n is the number of questions in the questionnaire.

The results of this study [Table 2](#) show that Cronbach's alpha values for 11 variables are 0.808, which is higher than 0.7 and is within the acceptable range. The data collected from the questionnaire is analyzed using SEM to explore the relationships between indicators and constructs, aiming to ascertain their contributions within the conceptual framework. SEM is a robust statistical approach that enables the testing of hypotheses regarding the connections between observed and latent variables. Its application facilitates the assessment of the validity and reliability of theoretical models in specific contexts, establishing it as a fundamental tool for examining intricate relationships across diverse disciplines. The SEM aims to validate the indicators and relationships identified in the theoretical framework's content analysis and determine the predictive value of the designed structure. This is achieved through examining eleven identified indicators and assessing the relationship between the variables of "common rationality," "collective decision-making," and "cohesion." To assess questionnaire reliability, Cronbach's alpha is utilized, while content and convergent validity are employed for validity assessment. Content validity is ensured by seeking opinions from university professors and experts in collective decision-making before distributing the questionnaires. Validity is confirmed when the T-value exceeds 1.96 and the

P-value is less than 0.05. The R^2 criterion, which represents the coefficient of determination, assesses the model's ability to explain and accurately predict dependent variables based on independent variables. In path analysis, factor loading measures the strength of the relationship between a latent variable and its observed variables, with an optimal value above 0.4. To evaluate the overall fit of the model, including both the measurement model and the structure, the Goodness-of-Fit (GOF) criterion is used as shown in [Eq. 2](#). This criterion helps determine the overall adequacy of the model ([Abri et al., 2021; Sarstedt et al., 2021](#)).

$$GOF = \sqrt{\overline{Communalities} \times R^2} \quad (2)$$

The $\overline{Communalities}$ value is calculated by averaging the Average Variance Extracted (AVE) values of the latent variables. Weak, medium, and strong values for the GOF criterion are 0.01, 0.25, and 0.36, respectively. The GOF criterion is used to assess the overall model fit, which includes both the structure and the measurement model.

RESULTS AND DISCUSSION

Data analysis

Data analysis is conducted using Smart PLS 2.0, SPSS, and Excel. The research's conceptual model, as depicted in [Fig. 2](#), is analyzed using Smart PLS 2.0.

In the presented model, the variable of common rationality is regarded as an autonomous factor, while cohesion is viewed as a reliant factor, and collective decision-making serves as a mediating variable. A model guide is shown in [Table 3](#).

[Table 3](#) shows the variables hidden in the model. Factor loading can be utilized to assess the extent of association between the latent variables and the observed variables. The factor loadings of the research model indices are presented in [Table 4](#).

[Table 4](#) displays the factor loadings connecting the latent and observed variables. As previously explained, any variables with a factor loading lower than 0.4 should be excluded from the model. In the computations, the factor loading between the variable of "coherence" and "trust-building" (C1) is 0.171 and therefore removed from the model. The factor loading in other indicators is more than 0.4 and they are not eliminated. Therefore, by removing the trust-building index (C1), the proposed research

model in the software needs to be analyzed once again. The output obtained from Smart PLS 2.0 software is shown in Fig. 3.

The evaluation criteria are employed to evaluate the degree to which the formulated model corresponds with the collected data. In case the model

does not meet the evaluation criteria, it is necessary to make modifications. The criteria obtained for fitting the conceptual model are presented in Table 5.

Based on the data presented in Fig. 3 and Table 5, it can be observed that the P-values for the relationships between the variables “common

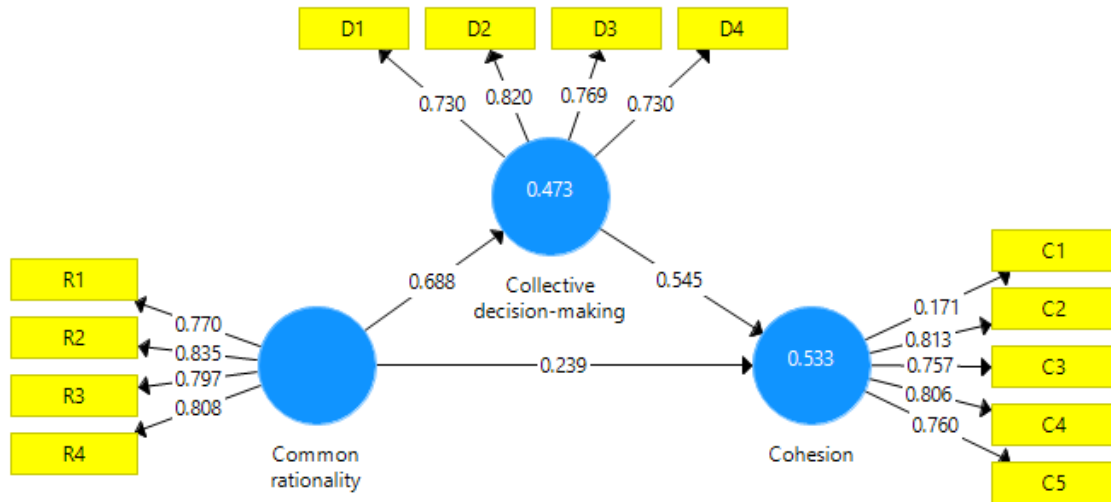


Fig. 2: Path coefficient of the model

Table 3: Guide to the indicators used in the structural equation model

Indicator	Description	Indicator	Description	Indicator	Description
R1	Common thoughts	D1	Voting	C1	Trust-building
R2	Common goals	D2	Information Sharing	C2	Alliance
R3	Common benefits	D3	Consultation	C3	Reaching consensus
R4	Common interests	D4	Team building	C4	Reducing conflicts
				C5	Coordination

Table 4: Factor loading of model indices

Row	Indicator	Factor loading	Row	Indicator	Factor loading	Row	Indicator	Factor loading
1	Common rationality → R1	0.770	5	Collective decision-making → D1	0.730	9	Cohesion → C1	0.171
2	Common rationality → R2	0.835	6	Collective decision-making → D2	0.820	10	Cohesion → C2	0.813
3	Common rationality → R3	0.779	7	Collective decision-making → D3	0.769	11	Cohesion → C3	0.757
4	Common rationality → R4	0.808	8	Collective decision-making → D4	0.730	12	Cohesion → C4	0.806
						13	Cohesion → C5	0.760

rationality → collective decision-making”, “collective decision-making → cohesion”, and “common rationality → cohesion” are all below 0.05. Additionally, the T-values exceed 1.96, indicating that these relationships are statistically significant at a 0.05 error level. The regression coefficient for “common rationality → collective decision-making” is 0.668, while for “collective decision-making → cohesion” it is 0.550, suggesting a positive and direct correlation between these variables. However, the regression coefficient for “common rationality → cohesion” is 0.234, indicating a weaker relationship between these two variables. In the following, a deeper interpretation of the regression coefficients and their practical implications in the context of collective decision-making and group cohesion:

a) *Common Rationality → Collective Decision-Making* ($r = 0.668$)

Interpretation: A regression coefficient of 0.668

suggests a strong positive relationship between common rationality and collective decision-making. This means that as common rationality increases, the quality and frequency of collective decision-making processes also increase.

Practical Implications: Organizations should invest in building common rationality among members through training, shared values, and open communication. This can lead to more effective and frequent collective decision-making. Also, emphasizing common goals and shared understanding can enhance the willingness and ability of team members to engage in collective decision-making, thereby improving overall decision quality.

b) *Collective Decision-Making → Cohesion* ($r = 0.550$)

Interpretation: The regression coefficient of 0.550 indicates a significant positive impact of collective decision-making on group cohesion. This suggests

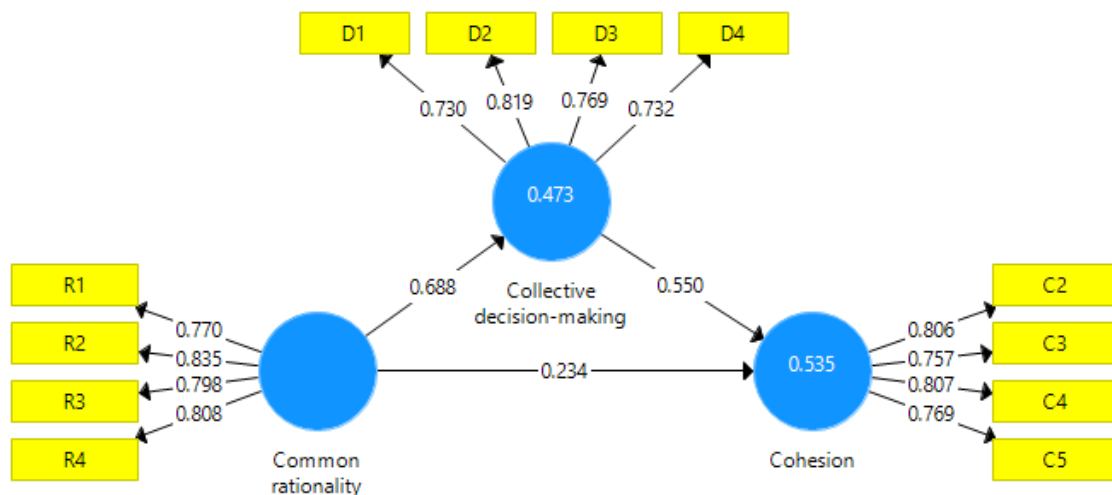


Fig. 3: The model is obtained using structural equation analysis

Table 5: Conceptual model evaluation criteria

Hypothesis	Causal relation	Regression coefficient (r)	Coefficient of Determination (r^2)	Mean (M)	Standard Deviation (STDEV)	T-Value	P-Value
H ₁	Common rationality → Collective decision-making	0.668	0.473	0.694	0.041	16.633	0.000
H ₂	Collective decision-making → Cohesion	0.550	0.535	0.555	0.091	6.046	0.000
H ₃	Common rationality → Cohesion	0.234	-	0.234	0.098	2.388	0.017

Table 6: Reliability and validity coefficients of model variables

Variables	Cronbach's Alpha	Composite Reliability	AVE	Q ² =(1-SSE/SSO)
Common rationality	0.819	0.879	0.645	0.403
Collective decision-making	0.762	0.848	0.583	0.309
Cohesion	0.793	0.865	0.616	0.362

that effective collective decision-making processes contribute substantially to the cohesion among group members.

Practical Implications: Facilitating collective decision-making can strengthen interpersonal relationships and trust, leading to higher group cohesion. As well, teams that are more cohesive due to collective decision-making are likely to perform better, as members are more aligned with the group's objectives and more supportive of each other.

c) *Common Rationality* → *Cohesion* ($r = 0.238$)

Interpretation: A regression coefficient of 0.238 indicates a weaker but still positive direct relationship between common rationality and cohesion. While common rationality does contribute to cohesion, its direct effect is not as strong as through the mediating variable of collective decision-making.

Practical Implications: The weaker direct relationship suggests that common rationality's primary influence on cohesion is mediated through collective decision-making. Therefore, efforts to improve group cohesion should focus on enhancing collective decision-making processes. Also, organizations should create environments that support both common rationality and collective decision-making to maximize cohesion. This can include fostering a culture of open dialogue and mutual respect, where shared rationality is a foundation for decision-making practices. Therefore, the regression analysis underscores the pivotal role of collective decision-making as a mediator between common rationality and group cohesion. By focusing on building common rationality and facilitating collective decision-making, organizations can significantly enhance group cohesion, leading to improved collaboration, performance, and overall organizational success. This holistic approach ensures that the benefits of common rationality are fully realized through effective and inclusive decision-making processes. The r^2 values for "collective decision-making" and "common rationality" are 0.473 and 0.535, suggesting a fairly accurate prediction for

these dependent variables and mediating. Table 6 presents the results for the Composite Reliability coefficient, Cronbach's alpha coefficient, and AVE, which are essential for evaluating the questionnaire's reliability and validity.

The questionnaire demonstrates good reliability as both Cronbach's alpha coefficient and the Composite Reliability coefficient exceed 0.7, as indicated in Table 6. This ensures the questionnaire's reliability is acceptable. Moreover, the AVE is utilized to assess convergent validity, with values exceeding 0.5 for all three variables, affirming the questionnaire's validity. Regarding the predictive power of the model, the Q² criterion is considered, with values surpassing 0.3, indicating a robust fit for model prediction. Lastly, the overall model fit is evaluated using the GOF criterion. Through the conducted calculations, a value of 0.469 is obtained for this criterion, implying an overall acceptable model fit as shown in Eq. 3.

$$GOF = \sqrt{\text{Communalities} \times R^2} = \sqrt{0.615 \times 0.358} = 0.469 \quad (3)$$

Based on the given explanations, considering that the obtained value exceeds 0.36, it can be concluded that the overall model fit is suitable (Abri et al., 2021; Sarstedt et al., 2021).

Discussion

The research highlights the significant importance of common rationality as a valuable societal resource in promoting participation and unity. Fig. 2 demonstrates that the direct relationship between common rationality and unity has a relatively low path coefficient (0.239), whereas the indirect pathway through collective decision-making exhibits higher coefficients (0.545 and 0.688). These results emphasize that although common rationality is crucial for the success of organizations, managers should utilize collective decision-making as a means to effectively enhance unity. Collective decision-making plays a substantial role as a mediator between common rationality and cohesion. Thus, managers aiming to leverage organizational common

rationality to enhance cohesion should prioritize collective decision-making. This approach harnesses the potential of common rationality to bolster cohesion by fostering synergy, minimizing biases, and elevating decision quality, ultimately leading to optimal solutions. By elucidating these relationships, this study incentivizes managers to adopt collective decision-making as a means to leverage common rationality for greater cohesion. Consequently, the current research validates hypotheses H1 and H2, which emphasize the indirect link from common rationality to cohesion through collective decision-making as a mediator, highlighting the significance of group involvement. Conversely, H3, proposing a direct impact of common rationality on cohesion without taking into account collective decision-making, is not supported. Previous studies have also shown that collective decision-making can positively affect group cohesion. For instance, research indicates that heightened levels of collective decision-making can significantly enhance team cohesion and overall group outcomes (McHugh *et al.*, 2016; Khaluf *et al.*, 2017). Moreover, the balance between accuracy and speed in group decision-making reveals that while larger groups may require more time to reach a consensus due to increased communication, the precision of their decisions can be enhanced. This interplay illustrates how collective decision-making processes have the potential to bolster group cohesion by yielding more precise and dependable outcomes (Hsieh *et al.*, 2020). Furthermore, investigations into social animal groups have also illustrated that information sharing and collective decision-making serve to fortify their group cohesion (Yan, *et al.*, 2024; Frank & Linsenmair, 2017; Sasaki & Pratt, 2018; Stroeymeyt *et al.*, 2014; Stuttard *et al.*, 2016). The findings of this study align with prior research and are further supported by similar studies that demonstrate the impact of collective decision-making on group cohesion. This study introduces a comprehensive conceptual model outlining the process of attaining group cohesion through collective decision-making, emphasizing the importance of carefully identifying effective indicators. Also, examining the latent variables' indicators in this study is crucial. Common rationality, collective decision-making, and cohesion are three latent variables, each consisting of multiple indicators for evaluation. In this study, we included four indicators for common rationality

in the collective, which encompass common goals (Tongo, 2015), common thinking (Liang *et al.*, 2021), common interests (Elster, 2020), common benefits (Ekwoaba *et al.*, 2019). Various indicators can be utilized to assess collective decision-making, such as information sharing (Dionne *et al.*, 2019), voting (Xu, 2019), consultation (Iaryczower *et al.*, 2018), team building (Lloyd *et al.*, 2013), and meetings (Bui, 1987). To measure cohesion, indicators of alliance (McHugh *et al.*, 2016), reaching consensus (Bosel *et al.*, 2017), reducing conflicts (Telem, 1988), and coordination (Sueur *et al.*, 2011) were used. All indicators, except for "trust-building" (C1), show appropriate factor loadings, which indicate their appropriateness in measuring the three hidden variables. It appears that the elimination of the "trust building" index indicates that the process of building trust is intricate, lengthy, and multifaceted, and is impacted by numerous factors. Furthermore, to establish trust, individuals must consistently demonstrate honesty, transparency, and loyalty over an extended period, while also strengthening the relationships among group members. Conversely, collective decision-making processes are frequently not time-consuming and do not provide sufficient opportunities to cultivate trust. Consequently, establishing trust through collective decision-making is challenging, despite the potential usefulness of this indicator in fostering greater group cohesion. However, it's important to acknowledge the study's limitations. Firstly, due to time constraints, data collection was confined to a single period, limiting the ability to observe long-term effects. Future research should consider conducting experiments over multiple periods for a comprehensive understanding. Secondly, as described in the methodology section, demographic factors like age, educational attainment, and gender are considered control variables in this study. Nevertheless, it seems that these factors have a notable impact on the adoption of the collective decision-making approach. Moreover, they may affect the level of cohesion achieved through this method. For example, individuals with higher levels of education are more inclined to employ this approach. Therefore, not accounting for these variables poses a constraint on the study. Thirdly, managers' comprehension of collective decision-making may vary, potentially leading to cognitive biases in decision-making processes. Addressing these limitations could

enhance the robustness of future studies in this area. Another significant limitation of this study is the failure to account for the impact of individual characteristics on collective decision-making. The individual traits of group members play a crucial role in shaping the process of collective decision-making, group cohesion, and shared rationality. Neglecting this influence can hinder the attainment of genuinely collective and cohesive decisions, as emphasized by theories like Social Value Orientation (SVO).

CONCLUSION

Collective decision-making is about the group reaching a single decision. Collective decision-making has many potential benefits for society members and managers, and all social actions are based on collective decision-making. Given the significance and relevance of this matter, the research's conceptual framework is formulated by considering the research background and hypotheses, and subsequently examined through SEM. The statistical analysis, based on the P-value and T-value, indicates that the associations among the variables of common rationality, collective decision-making, and Cohesion hold substantial importance at a significance level of 0.05. Considering the obtained factor loading, it can be said that except for the "trust-building" (C1), which is removed from the model, all defined indicators are good criteria for measuring the latent variables of common rationality, collective decision-making, and cohesion. In addition, the regression coefficients of all variables are above 1.96 and indicate that these variables have a significant and positive relationship with each other's latent variables. Therefore, according to the obtained data, it can be concluded that to reach a collective decision, there must be common rationality. To measure common rationality in the collective, indicators such as common thinking, common benefits, common goals, and common interests must be measured. The stronger these indicators in a group, the better the collective decision-making. For collective decision-making, there are tools and indicators such as voting, information sharing, meetings, consultation, and team building. Using these methods, collective decision-making can be implemented. One of the most important consequences of the collective decision-making method in the organization and society is increased cohesion. To measure the degree of cohesion in an organization, indicators such as

alliance, reaching consensus, reducing conflicts, and coordination among members can be used. The confirmation of both research hypotheses and the rejection of one indicates that this study delves into the factors influencing collective decision-making and its outcomes by analyzing theoretical frameworks and gathering insights from experts. In this framework, the influence of common rationality on cohesion is mediated by collective decision-making. Hence, while common rationality is a valuable resource for organizations and societies, leaders and policymakers aiming to leverage it for enhancing cohesion need to operationalize this resource through collective decision-making. Leaders play a crucial role in fostering common rationality by promoting a shared vision and facilitating collective decision-making. Training leaders in these areas can have a cascading positive effect on group cohesion. Organizational policies should emphasize the importance of shared understanding (common rationality) and collective decision-making. This can involve regular team meetings, participatory decision-making frameworks, and initiatives that build mutual trust and understanding. Collective decision-making serves as an appropriate managerial approach that effectively enhances cohesion and propels organizations toward their objectives. There are three potential avenues for future research. Firstly, investigating the reception or refusal of collective decision-making by managers in various societies holds significant importance from a cross-cultural standpoint. This research proposal aims to comprehend how managers from diverse cultural backgrounds either embrace or shun collective decision-making. Secondly, exploring the obstacles to collective decision-making, such as cognitive biases, can enhance the utilization of collective decision-making techniques. Cognitive biases like confirmation bias, anchoring, and groupthink can greatly impede the collective decision-making process by distorting perceptions and judgments. Identifying these obstacles can aid in devising strategies to mitigate them and encourage the adoption of collective decision-making approaches. The third area involves scrutinizing the influence of moderating variables on collective decision-making, which are regarded as control factors in this investigation. This proposal delves into how moderating variables such as gender, age, and managerial experience impact collective decision-making. By treating these variables as

control elements, this study seeks to isolate their effects and gain a deeper understanding of how they influence the acceptance and efficacy of collective decision-making.

AUTHOR CONTRIBUTIONS

S.M. Mirbagheri conducted the literature review and methodology, compiled the data, and drafted the manuscript. A. Rafiei Atani was responsible for performing the literature review and analyzing the data. M.R. Parsanejad contributed to the results and discussion sections. R. Jafari provided revisions to the article concerning its literary structure and composition.

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CONFLICT OF INTEREST

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

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ABBREVIATION

AVE	Average Variance Extracted
C	Cohesion
D	Collective decision making
H	Hypothesis

GOF	Goodness of fit
R	Common rationality
SEM	Structural equation modeling
r	Regression coefficient
r ²	Coefficient of determination
M	Mean
STDEV	Standard Deviation
SVO	Social value orientation

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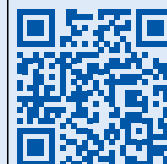


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ORIGINAL RESEARCH PAPER

Integrating human resource management in urban workforce development:
A focus on salary increments

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ABSTRACT

BACKGROUND AND OBJECTIVES: This study investigates the impact of demographic factors and skill enhancements on salary increments at Guangzhou Wangming Water Joy Design Co., Ltd., a leading Chinese company in the water park equipment sector using Light-Resin Transfer Molding technology. It aims to propose targeted strategies for boosting employee welfare and enhancing the company's competitive edge and organizational success.

METHODS: Employing a quantitative descriptive research approach, the study collected data through survey questionnaires from 224 employees, including 196 teachers and 28 supervisors. The analysis involved calculating percentages and frequencies to describe respondent demographics and using weighted means to assess factors influencing salary increments and employee welfare.

FINDINGS: Founded in 2006 and now operating in over 30 countries, the company demonstrates a significant global presence. Workforce analysis revealed a predominantly male demographic (63.33%) and a significant concentration of employees aged 36-45 years (83.33%), indicative of a mature and experienced employee base. Crucially, skill enhancement correlated strongly with salary progression, and structured professional development was linked to high employee satisfaction. Key measures included a mean satisfaction rating of 4.15 for work-life balance initiatives and a mean effectiveness rating of 4.20 for training programs.

CONCLUSION: Based on the findings, it is recommended that the company integrate historical narratives into employee training programs to foster organizational pride and loyalty. Furthermore, expanding diversity and inclusion efforts, emphasizing continuous learning, enhancing welfare programs, and instituting adaptive feedback mechanisms are essential for addressing the complexities of employee demographics and improving salary increment practices. These strategies are vital for promoting employee welfare and reinforcing the company's competitive stance in the global market.

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INTRODUCTION

As China advances through its post-COVID-19 economic recovery, the need to reassess compensation strategies across industries is evident. Historically, China's State-Owned Enterprises (SOEs) have implemented performance-linked wage increments that have significantly influenced both the domestic and global economic landscapes (Hsu, 2021). However, the 2008 financial crisis highlighted critical inefficiencies and disparities within these wage structures, which led to market imbalances and widespread employee dissatisfaction. These challenges underscore an urgent need to refine compensation practices to better align with contemporary economic conditions and workforce expectations, ensuring that wage strategies are both competitive and equitable. Current scholarship on wage reforms in China primarily focuses on their macroeconomic impacts and shifts towards market-oriented practices since the late 20th century. However, a significant gap exists in understanding the specific effects of these wage policies on employee motivation, satisfaction, and organizational loyalty, particularly within high-growth sectors like the water park equipment industry. This lack of micro-level analysis underscores the need for research that explores how wage adjustments respond to global economic pressures and internal market demands. Effective compensation strategies are essential for organizational growth and success, as evidenced by successful incentive systems in companies like International Business Machines Corporation (IBMC) and Microsoft, which have been shown to significantly enhance productivity, creativity, and innovation (Santos, 2023). This research reviews critical literature on the evolution of China's wage structure, employment shifts, and the effects of compensation restrictions on labor productivity. Despite significant socio-economic changes since China's economic reform in 1978, including privatization and industrial restructuring, there remains a notable gap in comprehensive, longitudinal analysis of wage trends, hindered by the scarcity of consistent data. Notably, from 1986 to 1997, despite robust employment growth, wage growth slowed to 3.9% annually, affected by high inflation and political instability. A major shift occurred from 1998 to 2007 during China's World Trade Organization (WTO) accession and the restructuring of SOEs, where wage growth accelerated

to 13.2% annually (Qian and Weingast, 1997). These wage dynamics were also influenced by market forces and regulatory changes, leading to increased industrial wage dispersion and a widening skilled-unskilled wage gap (Jia and Dong, 2012). Additionally, minimum wage regulations have significantly impacted employment and innovation (Li *et al.*, 2022; Fang and Lin, 2015). Historical challenges within SOEs, such as low productivity and high debt, have necessitated shifts from being instruments of political stability to more competitive entities, often causing talented individuals to seek better opportunities in more lucrative sectors. This complex interplay of factors underscores the critical need for targeted research into the specific impacts of wage policies within China's evolving economic landscape. The restructuring of SOEs in China from the mid-1990s to 2003 led to significant workforce reductions, affecting about 40 million workers, and improved labor productivity, with a third of the productivity gains attributed to reductions in inefficient SOEs (Nahm and Tani, 2012; Pandit, 2022). These changes not only raised wages for remaining employees but also resulted in increased urban unemployment, particularly impacting older workers, women, and the less educated, and shifted the labor force composition by expanding the pool of unskilled labor (Song *et al.*, 2011; Fuest and Liu, 2015). Additionally, wage disparities widened significantly, with the Southeastern and Bohai regions seeing wages outpace other areas by 30-40% due to rapid economic growth in these regions (Zhang, 2021). This period of economic transformation was further characterized by major policy shifts including the Xiangang policy of 1997, which aimed to modernize corporate governance and separate employment from social services provision, significantly altering labor market dynamics and youth employment outcomes (Bach *et al.*, 2021). The era also saw extensive advocacy for structural labor market reforms from international bodies, leading to a substantial reduction in state employment protection and the dismissal of millions of public sector workers (Blyzniuk, 2020; Zhang 2021). Amid these changes, the study investigates the impacts of compensation restrictions on labor productivity in SOEs, applying social equity and efficiency-wage theories. These theories suggest that fair compensation is crucial for employee motivation; however, high wages in SOEs have not consistently

improved productivity, indicating inefficiencies in the wage-performance relationship (Yu *et al.*, 2013; Card *et al.*, 2012; Zhu *et al.*, 2022). Incorporating modern challenges, this study also considers the influence of digital leadership on organizational performance, highlighting that effective digital strategies can enhance competitiveness in a rapidly evolving marketplace (Arabiun *et al.*, 2024). Moreover, team performance is shown to be pivotal for digital startups during internationalization, enhancing learning and trust among employees and boosting global competitiveness (Tajpour, 2023). This study aims to investigate the structuring and implementation of contemporary wage strategies that enhance employee satisfaction and organizational performance within China's unique industrial sectors. Focusing on Guangzhou Wangming Water Joy Design Co., Ltd., the research assesses the direct effects of annual salary increases on employee motivation and their subsequent impact on productivity and corporate competitiveness. This exploration delves into the nuanced effects of salary adjustments on the company's workforce, examining factors such as the company's business nature, years of operation, employee demographics, salary structures, and the geographical scope of its operations. Key aspects under scrutiny include gender, age, job titles, department affiliations, tenure, and participation in training and seminars. The study also investigates the myriad factors influencing salary increments, including skills, education, job complexity, and performance metrics. This not only aims to identify gaps within the existing salary increment system but also seeks to engage a wide range of stakeholders—from managerial staff to frontline employees—to enhance strategic planning and implementation of salary adjustments that improve employee welfare. Engaging stakeholders in decision-making processes is crucial, as highlighted by Martinez *et al.* (2021), and involves integrating stakeholders into governance, strategy, and operations to ensure authenticity, equity, and sustainability in partnerships (Ardiana, 2022). This approach is particularly vital in sectors like construction where unique challenges necessitate comprehensive stakeholder involvement (Ebekozen *et al.*, 2023), and in sustainability reporting and Corporate social responsibility decision processes to enhance the credibility of corporate reports and foster organizational embeddedness (Ardiana, 2021).

Acknowledging its limited scope to Guangzhou Wangming Water Joy Design Co., Ltd., the study recognizes that its findings might not universally apply across different organizational contexts or geographies. Nonetheless, the insights gained are intended to provide a foundation for refining strategic directions and improving organizational practices that enhance employee satisfaction and performance. For enterprise owners, managers, and employees, these findings can drive better management of operations and foster a motivated workforce. Additionally, this research serves as a valuable learning journey for the researcher, enriching the academic and practical discourse on salary management and employee welfare strategies. The objective is to critically assess the impact of salary increments on employee satisfaction and organizational success, providing actionable insights into integrating human resource management with urban workforce development strategies. Conducted in Guangzhou, China, in 2023, this study aims to contribute valuable insights to both the academic community and business practitioners. The research employs a quantitative descriptive design, focusing on survey data collected from employees at Guangzhou Wangming Water Joy Design Co., Ltd. This methodological approach involves analyzing demographic data and assessing factors influencing salary increments through statistical means such as percentages, frequencies, and weighted means. This quantitative focus allows for a precise measurement of the impact of various factors on salary increments and employee welfare, providing clear, data-driven insights into the current compensation practices. The structure of the paper is methodically designed to navigate through various dimensions of wage policy research within the context of China's evolving industrial landscape. It begins with a comprehensive Literature Review, which delves into the existing body of research on wage policies. This section critically examines theoretical frameworks and pinpoints the significant gaps that persist in understanding the effects of these policies at the organizational and employee levels. Following this, the Methods section describes the research design and the methodologies employed for data collection and analysis, providing clarity on how these methods are adeptly aligned to address the research questions posed. The Results section then unfolds, presenting a detailed analysis of

the data gathered through both quantitative surveys and qualitative interviews, illustrating how wage adjustments impact employee motivation and organizational performance. In the Discussion section, the implications of these findings are explored in depth, relating them to the theoretical discussions initiated in the literature review and highlighting how the new data either supports or challenges existing theories. Finally, the Conclusion and Implications section synthesizes the findings, discussing their broader implications for policy and practice while also suggesting directions for future research. This structured approach ensures a logical flow and comprehensive understanding of the study's contributions to the field of wage policy and organizational studies. This study delves into the dynamic interplay between salary increments and employee welfare within Guangzhou Wangming Water Joy Design Co., Ltd., set against the backdrop of China's evolving economic landscape. By quantitatively analyzing the impact of wage policies on employee motivation and organizational performance, this research aims to fill a critical gap in the current understanding of compensation management in high-growth industries. Theoretical contributions are made by applying established economic theories in a new context, thereby offering fresh insights into how nuanced adjustments to wage structures can enhance both individual and corporate outcomes. This paper seeks not only to bridge the theoretical gaps but also to provide empirical evidence that supports the development of more effective human resource strategies in similar contexts.

MATERIALS AND METHODS

This study adopts a quantitative descriptive design to investigate the effects of annual salary increases at Guangzhou Wangming Water Joy Design Co., Ltd., within the dynamic economic environment of China. To elevate methodological rigor, the study integrates expert assessments to complement the primary survey-based data collection. Data is collected using a survey questionnaire that has been carefully developed from relevant literature and pre-tested to ensure clarity and reliability. The questionnaire is distributed among a diverse group of company managers, employees, and staff, selected through stratified random sampling to

ensure a comprehensive representation of different demographic and role-specific groups. This approach allows for a more specified analysis of data across various employee categories. Expert assessments, including consultations with senior Human Resource professionals and industry experts, are utilized to refine survey tools and enhance data interpretation. These assessments help in understanding the intricate dynamics of salary increments and their impact on employee motivation and productivity. Furthermore, the study extends beyond simple weighted averages in data processing, applying more sophisticated statistical techniques to delve into the relationships between salary increments and key performance indicators. This refined analysis leverages advanced quantitative methods to assess the impact of various factors considered in salary increments, including employee performance, tenure, and market competitiveness. The research is conducted in Guangzhou, a major economic and trade hub in China, which provides a pertinent context for exploring salary trends within one of the country's leading firms. This setting is crucial for contextualizing the study's findings and assessing their applicability to similar industrial scenarios, offering insights that are relevant both locally and in broader economic contexts.

RESULTS AND DISCUSSION

Profile of Guangzhou Wangming Water Joy Design Co., Ltd.

Guangzhou Wangming Water Joy Design Co., Ltd., nestled in the vibrant city of Guangzhou, China, is at the forefront of water park equipment manufacturing. Since its inception in 2006, the company has carved a niche for itself by harnessing the innovative Light-Resin Transfer Molding (L-RTM) technology to create an array of water attractions, including slides and wave pools. These products stand out for their aesthetic appeal and immersive experiences, capturing the essence of fun and excitement sought by tourists worldwide. Over the years, Guangzhou Wangming Water Joy Design Co., Ltd. has grown into a market leader within the water park sector, a testament to its dedicated service and pioneering designs. With a robust workforce of 665 individuals, the company embodies a culture of diversity and innovation. The team comprises 15 managers, 300 employees, and 350 other staff members, each contributing to the

dynamic and creative environment that is pivotal to the company's operations and success. The salary structure at Guangzhou Wangming Water Joy Design Co., Ltd. reflects a commitment to competitive compensation and employee recognition. Survey findings indicate a wide salary range, with most earnings falling between \$30,000 and \$70,000, alongside performance-based incentives that underscore the value placed on exceptional work and achievement. This structured compensation approach not only aims to attract top talent but also to nurture a motivated and engaged workforce. Marking its presence on the global stage, the company boasts of projects in over 30 countries and regions. This extensive international footprint reveals Guangzhou Wangming Water Joy Design Co., Ltd.'s ability to adapt its offerings across diverse cultural and geographical landscapes, showcasing its global influence in the amusement industry. Such a wide-reaching operation not only speaks to the company's expansive vision but also its understanding of the nuanced demands of the global market, positioning it as a significant player in the international arena.

Profile of the employee respondents

The demographic analysis at Guangzhou Wangming Water Joy Design Co., Ltd. reveals a significant gender disparity, with males comprising 63.33% (190) of respondents and females 36.67% (110). This imbalance underscores a potential area for enhancing gender diversity, which, as [Hoogendoorn, Oosterbeek, and van Praag \(2013\)](#) suggest, can contribute to greater innovation and financial performance. Additionally, the predominance of employees within the 36–45 age group (83.33%, 250 respondents) highlights a workforce rich in experience but with limited representation from both younger and older age brackets. [Zacher \(2015\)](#) notes the value of a diverse age range in enhancing organizational success through a dynamic mix of adaptability and experience. These demographic insights stress the importance of aligning salary increments with the diverse needs and contributions of all employees to ensure equitable compensation practices. The company's hierarchy is reflected in the distribution across various positions, with 60% of employees in mid-level roles, 26.67% in senior positions, 5% as managers, 6.67% at entry-level, and 1.67% as executives. This structure indicates

that mid-level employees, who form the backbone of daily operations and long-term projects, may have different motivational and financial recognition needs compared to those in senior or entry-level positions. [Manzoor \(2011\)](#) emphasizes the linkage between employee motivation and organizational effectiveness, suggesting the necessity of recognizing contributions across all levels. Additionally, 66.67% of employees work in Production, highlighting the company's operational focus, while smaller segments in IT (6.67%) and Research and Development (R&D) (10.00%) underscore the areas of specialized expertise. A significant 16.67% in the Human Resources department reflects the emphasis on employee management and development. Salary increments in these departments should reflect the market value of the skills and the strategic importance of the roles to retain top talent and foster a positive organizational culture. The tenure of employees also reveals insights into job satisfaction and retention, with 83.33% having been in their roles for 4-6 years, indicating stability. However, the roles and tenure should be evaluated not just for longevity but for the value brought through performance and adaptability ([Santos, 2020](#)). The company's commitment to professional development is evident, with a majority participating in 6-10 training sessions annually, which is essential for career advancement and organizational success ([Santos, 2023](#)).

Factors considered for salary increments

[Table 1](#) highlights the importance placed on employee skills and knowledge about salary increments at Guangzhou Wangming Water Joy Design Co., Ltd. All the weighted mean scores are close to the maximum value of 4, indicating that the company frequently and consistently considers skills and knowledge for salary increments. It signifies that the company places a high premium on employees' competencies and their continuous learning. The significant emphasis on employee skills and knowledge aligns with global trends and best practices in HR management. Research suggests that employees' competencies play a pivotal role in determining their pay scales, as these competencies contribute directly to organizational performance and productivity ([Armstrong and Taylor, 2020](#)). Organizations that align their compensation strategy with employee skills and knowledge ensure a more equitable pay distribution,

which in turn leads to increased motivation and job satisfaction (Pfeffer, 1998). Furthermore, the encouragement for employees to enhance their skills (Item 2) and the provision of opportunities for them to do so (Item 3) reflect the company's commitment to professional development. According to a study by the Society for Human Resource Management (SHRM, 2019), continuous learning opportunities are among the top drivers of employee engagement. This is because they not only ensure that employees remain up to date in their respective fields but also demonstrate an organization's commitment to its workforce's growth and development. Transparency, as highlighted in items 4 and 5, is another crucial element in the pay increment process. A transparent process fosters trust, as employees understand the criteria used to determine their salary increments, reducing the chances of discontentment and disputes (Cappelli and Tavis, 2016).

Table 2 discusses employee education and experiences as one of the bases for salary increments.

The majority of the employee respondents agreed that employee education and experiences have a significant impact on organizational success. From improved job performance and increased innovation to higher employee satisfaction and enhanced adaptability, investing in employee development yields numerous benefits for companies. Research indicates that education and experiences positively impact employee job performance. According to a study conducted by Singh and Loncar (2010), employees with higher levels of education exhibit superior performance due to their enhanced knowledge, skills, and adaptability. This improved performance can lead to increased productivity, better customer satisfaction, and higher profitability. In today's rapidly evolving business environment, organizational success relies on an adaptable workforce. By investing in employee education and experiences, organizations create a foundation for continuous learning. According to a study by Marquardt (2011), continuous learning helps

Table 1: Employee skills and knowledge

Item Statements	Weighted Mean	Description
Are salary increments based on employee skill evaluations?	3.95	Always
Are employees encouraged to improve their skills to receive higher salary increments?	3.98	Always
Does the company provide opportunities for employees to enhance their skills?	3.93	Always
Are employees informed about how their skill evaluations affect their salary increments?	3.97	Always
Is there a transparent process for employees to understand the link between skill evaluations and salary increments?	3.96	Always
Average Weighted Mean	3.96	Always

Table 2: Employee education and experiences

Item Statements	Weighted Mean	Description
Employees with higher levels of education are typically considered for salary increments.	3.97	Always
Years of experience in a particular field is also a significant factor considered by employers when considering salary increments.	4.00	Always
Specific certifications or training programs that demonstrate expertise in a certain area can also be a crucial factor considered when deciding on a salary increment.	3.93	Always
An employee's track record of achieving successful outcomes and consistently meeting or exceeding performance targets is another factor that can boost his/her chances of receiving a salary increment.	4.00	Always
Attainment of leadership roles or having responsibilities that require strong managerial skills is likely to increase the chances of receiving a higher salary increment.	3.97	Always
Average Weighted Mean	3.97	Always

Table 3: Employee nature and degree/complexity of the job

Item Statements	Weighted Mean	Description
Are salary increments based on the complexity of job responsibilities?	3.90	Always
Do employees receive salary increments when they take on additional job responsibilities?	3.94	Always
Is there a clear link between job responsibilities, complexity, and salary increments?	3.92	Always
Are employees informed of how their job responsibilities affect their salary increments?	3.93	Always
Are job responsibilities and complexity regularly reviewed to ensure fair salary increments?	3.73	Always
Average Weighted Mean	3.88	Always

employees develop new skills, stay up-to-date with industry trends, and embrace change. Such flexibility and adaptability foster organizational resilience and allow companies to stay ahead of the curve.

The data presented in [Table 3](#) underscores the significant emphasis Guangzhou Wangming Water Joy Design Co., Ltd places on the complexity and nature of job roles when determining salary increments. With all the weighted mean scores hovering close to the maximum value of 4, it is evident that the company consistently factors in job complexity during salary reviews. The slightly lower score of 3.73 for regular reviews of job complexity and responsibilities suggests there might be occasional lapses in consistency, but the average weighted mean of 3.88 still indicates a strong recognition among employees of the role job complexity plays in salary decisions. The notion of linking salary increments to job complexity is rooted in the idea of compensating for cognitive demands and additional responsibilities that come with intricate roles. This approach recognizes that as roles become more intricate, they require a higher degree of expertise, decision-making, and problem-solving skills ([Martin and Bartol, 1998](#)). By ensuring that salary increments correspond to these complexities, organizations can promote fairness and motivate employees to take on more challenging roles. Furthermore, providing clear communication to employees about how their job responsibilities affect salary adjustments (Item 4 with a score of 3.93) is pivotal. Transparent communication can cultivate trust, reinforce the perception of fairness, and diminish potential misunderstandings or grievances ([Greenberg, 1990](#)). The regular review of job responsibilities and complexities (Item 5) is crucial for maintaining an equitable salary structure,

especially in fast-evolving industries. As job roles evolve, ensuring that salary structures align with these changes becomes essential for retaining talent and ensuring employees feel their contributions are justly rewarded ([Milkovich, Newman, and Gerhart, 2017](#)).

In [Table 4](#), the assessment of employee length of service and loyalty at Guangzhou Wangming Water Joy Design Co., Ltd. is depicted. The results indicate that salary increments are consistently linked to employees' length of service and loyalty, with this consideration often applied. While employees with longer service and demonstrated loyalty frequently receive higher increments, there is room for improvement in clearly communicating the link between length of service, loyalty, and increments. The average weighted mean of 3.20 suggests that the company acknowledges the importance of rewarding long-serving and loyal employees through increments. However, the organization could enhance its communication regarding the impact of length of service and loyalty on increments to improve transparency and employee understanding. Aligning with best practices, organizations that recognize and reward employee loyalty tend to foster higher levels of engagement and job satisfaction ([Eisenberger et al., 1997](#)). The findings are in line with the research conducted by [Brockner et al. \(1992\)](#), which emphasizes that equitable treatment, such as rewarding length of service, can positively impact employee morale and perceived fairness in compensation systems. The communication of the link between length of service, loyalty, and increments is pivotal in maintaining employee trust and commitment ([Gerhart et al., 2009](#)). Therefore, enhancing the transparency of this connection

through effective communication channels could potentially enhance the perceived fairness of the salary increment process and consequently bolster employees' motivation and engagement.

In Table 5, the evaluation of employee performance regarding physical targets and behavioral aspects at Guangzhou Wangming Water Joy Design Co., Ltd. is presented. The findings indicate that the company consistently considers individual employee performance when determining salary increments. Employees are well informed about the performance metrics used to assess their eligibility for salary increases. Performance reviews are conducted regularly to evaluate individual employee performance, and there is a transparent process for employees to seek clarification on salary increments. The average weighted mean of 3.89 suggests that the company places a significant emphasis on linking employee performance to compensation decisions. This practice aligns with the research by Santos (2023), which underscores the motivational impact of performance-based pay. Organizations that connect rewards with employee performance tend to foster higher levels of

engagement and productivity. Moreover, the emphasis on providing feedback and maintaining transparency in the salary increment process positively affects employee morale and job satisfaction. According to a study by Deloitte (2018), frequent feedback and open communication between employees and employers contribute to a more positive work environment and can drive higher levels of performance. The findings further align with the principles of organizational justice, where fair treatment in compensation matters enhances employee trust and commitment (Colquitt et al., 2001). This, in turn, has the potential to improve overall organizational performance.

Impact on managers vs. Employees

In analyzing the effects of salary increases, it is essential to consider the varying impacts on managerial and non-managerial staff. Managers often receive performance-based incentives that affect their perception of salary increases differently from non-managerial staff, who may place higher value on direct salary increments (Zhang et al., 2016). Non-financial factors such as supportive management,

Table 4: Employee length in service

Item Statements	Weighted Mean	Description
Are salary increments based on employee length of service and loyalty?	3.98	Always
Do employees with longer service and demonstrated loyalty receive higher salary increments?	3.53	Often
Is there a clear link between length of service, loyalty, and salary increments?	3.76	Often
Are employees informed about how their length of service and loyalty affect their salary increments?	3.28	Always
Is there a transparent process for employees to understand the link between length of service, loyalty, and salary increments?	3.97	Always
Average Weighted Mean	3.20	Often

Table 5: Employee performance (on physical targets and behavioral)

Item Statements	Weighted Mean	Description
Does the company consider individual employee performance when determining salary increments?	3.95	Always
Are employees aware of the performance metrics used to evaluate their eligibility for salary increases?	3.85	Always
Are performance reviews conducted regularly to assess individual employee performance?	3.80	Always
Do employees receive feedback on their performance about salary increment decisions?	3.95	Always
Is there a transparent process for employees to appeal or seek clarification on salary increments?	3.90	Always
Average Weighted Mean	3.89	Always

quality facilities, and training opportunities play a crucial role in job satisfaction for non-managerial employees, often outweighing financial incentives (Lamba *et al.*, 2021). Additionally, job satisfaction mediates the relationship between compensation, motivation, organizational commitment, and employee performance (Indrayani and Awis, 2020). Linking managerial salary increases to workplace wellness initiatives, rather than solely outcomes, can foster a healthier, more supportive work environment (Robbins and Wansink, 2016). The differential impacts of job stress factors like task overload, limited time, and role ambiguity also highlight the distinct experiences of managerial versus non-managerial staff, affecting their performance and organizational roles differently (Noermijati and Primasari, 2015). Moreover, in sectors such as healthcare, the authority of owner-managers over policies and resources significantly influences workforce retention and compensation structures (Huang and Bowblis, 2018). Understanding these nuanced effects of salary increments across different employee categories is vital for tailoring incentive structures to enhance job satisfaction, motivation, and overall organizational performance effectively. Recognizing and addressing the diverse motivations and priorities of both managerial and non-managerial employees enables companies to optimize their HR strategies and improve organizational outcomes. The response to salary increments varies significantly across different age groups within a company. Younger employees, typically under the age of 30, often prioritize career advancement over immediate salary increases, whereas older employees may value stability and higher immediate compensation. These differences highlight the importance of tailored compensation strategies to meet diverse expectations and enhance overall employee satisfaction. Understanding age diversity in the workforce is essential for effectively managing the varying preferences of employees at different career stages (Humboldt *et al.*, 2022). Research suggests that age diversity in organizations can leverage unique perspectives and experiences that various age groups bring, which is crucial for team outcomes (Schneid *et al.*, 2016). Furthermore, addressing age-based stereotype threats and promoting active aging are important for creating an inclusive and supportive work environment (Oliveira and Cabral-Cardoso, 2017). By recognizing and embracing age diversity,

organizations can create a workplace culture that values contributions from all age groups, leading to enhanced employee satisfaction, engagement, and improved organizational performance. Employees' valuation of salary increments often varies by department, reflecting the distinct nature of their work and departmental goals. For example, production department employees typically appreciate regular, smaller increments that acknowledge their consistent output, whereas research and development (R&D) staff might favor larger, milestone-based raises that reward breakthroughs and innovations (Gerull *et al.*, 2021). Tailoring compensation strategies to match these differing preferences is crucial for maintaining motivation and ensuring employees feel valued. Implementing specific policies such as milestone-based raises for R&D can drive innovation, while regular increments in production can recognize and reinforce consistent performance (Ding *et al.*, 2022). Understanding these compensation preferences across departments enhances overall employee satisfaction and engagement, contributing significantly to the organization's ability to attract and retain talent, drive performance, and boost productivity. By acknowledging and addressing how different departments value salary increments, organizations can create a more equitable and motivating compensation structure. Such strategies ensure that employee contributions are recognized in ways that align with individual and departmental goals, fostering a culture of appreciation and alignment with broader organizational objectives, leading to greater employee satisfaction and overall organizational success. To drive greater organizational success, Guangzhou Wangming Water Joy Design Co., Ltd. can significantly benefit from a nuanced understanding of how strategic salary increments can bolster employee motivation and productivity. By recognizing and addressing the diverse needs and preferences within the company, the organization can tailor its compensation strategies effectively. This tailored approach involves considering factors such as age, departmental differences, and individual job functions, creating a compensation structure that aligns with specific employee expectations and organizational goals (Janib *et al.*, 2021). Understanding the impact of salary increments across various demographic groups, including gender-based salary differences and the influence of workload on performance, is essential

for designing fair and equitable compensation policies that meet the specific needs of the workforce (Zhu et al., 2020). Additionally, exploring how career commitment and job satisfaction mediate the relationship between workload and performance can provide deeper insights into the factors that drive employee motivation and productivity (Altindag et al., 2020). Moreover, fostering cooperative relationships between departments and enhancing knowledge coupling can significantly boost collaboration and innovation across the organization (Huiping and Yang, 2021). By incentivizing research quality and productivity, the company can further encourage innovation and enhance performance (Zhao et al., 2018). Integrating fairness and satisfaction perceptions into compensation structures and addressing the impact of stress from inadequate salaries on employee well-being is crucial for creating a supportive work environment that promotes retention and satisfaction (Jiang et al., 2023). Finally, leveraging advanced data analytics, such as data mining models for employee churn prediction and safety measures, can help the company proactively address turnover issues and ensure a stable workforce (Viswanadapalli, 2021). In summary, by integrating insights from diverse research on salary, performance, and employee well-being, Guangzhou Wangming Water Joy Design Co., Ltd. can develop a comprehensive and tailored approach to strategic salary increments, thereby not only motivating employees but also propelling organizational success. The results of this research illustrate that strategic salary increments tailored to the unique needs of different employee groups at Guangzhou Wangming Water Joy Design Co., Ltd. significantly enhance job satisfaction and productivity. By adopting a comprehensive compensation strategy that acknowledges the varied preferences across age groups, departments, and job functions, the company not only fosters a motivated workforce but also drives broader organizational success, thereby contributing positively to the community by setting a standard for thoughtful employee compensation practices.

Propose a welfare plan for the employee

To prioritize the well-being of its workforce, a comprehensive Employee Welfare Plan was proposed, focusing on nurturing the physical, emotional, and financial health of its employees. This initiative aims to cultivate a supportive and enriching work

environment, thereby encouraging a well-rounded work-life balance, facilitating holistic development, and fostering a profound sense of community among employees. The plan is structured around several key focus areas, each with specific objectives, strategies, and activities tailored to meet the diverse needs of the workforce. Understanding the importance of health and wellness, the plan includes providing employees and their immediate families with comprehensive health insurance coverage. This is complemented by regular health check-ups, preventive screenings, and immunizations to ensure both mental and physical well-being. To encourage physical fitness, subsidized gym memberships, and wellness programs are offered alongside mental health resources, including counseling services and stress management workshops. These initiatives are overseen by the Mental Health Services Team and the Health Education Team, with a commitment to ongoing support throughout the year. Resources for these programs include health educators, mental health professionals, and funding for counseling sessions and facility partnerships. The plan also addresses the need for a supportive work-life balance. Strategies include offering paid time off and flexible working hours to accommodate personal responsibilities, encouraging remote work options for a more flexible work environment, and providing parental leave and support programs. The Human Resources Department spearheads these efforts, with an initial needs assessment phase followed by development, implementation, and evaluation phases, all requiring the expertise of HR professionals, trainers, and financial support. To foster employee growth, the plan includes training and development programs aimed at enhancing professional skills and career growth opportunities. This includes sponsorship for relevant certifications, workshops, and conferences, as well as regular performance evaluations with constructive feedback and personal development plans. These initiatives are a collaborative effort between the Human Resources Department and department managers, with ongoing sessions scheduled to ensure continuous development. Resources for this focus area include training materials, budget allocations for external trainers, and evaluation tools. Recognizing the importance of financial security, the plan offers financial assistance through retirement savings plans with employer-matching contributions, educational

assistance for further studies, and employer loans for unexpected financial hardship. These efforts are managed by the Accounting and Budget Offices, ensuring ongoing support for employees' financial well-being. Improving the work environment to enhance employee morale and well-being is another critical aspect of the plan. This includes ergonomic workstations, relaxation areas, and a culture of respect, openness, and inclusion. Necessary tools and resources are provided to enhance productivity and job satisfaction, with the Human Resources Department and the Employee Welfare Committee collaborating to ensure a positive work environment. To ensure the successful implementation and continual improvement of the Employee Welfare Plan, a dedicated committee oversees its execution, monitors its effectiveness, and adjusts based on employee feedback and evolving needs. Regular surveys and feedback sessions are integral to this process, highlighting the organization's commitment to its valued workforce's holistic well-being.

Limitations and future research

This study has addressed key aspects of salary increments and employee motivation at Guangzhou Wangming Water Joy Design Co., Ltd. However, its findings are limited by the focus on a single company within the L-RTM technology sector, potentially limiting the generalizability of the results to other industries or geographic regions. Additionally, the quantitative nature of our data collection may not capture the depth of employee perceptions and motivations that qualitative methods could reveal.

Future research should consider broadening the scope to include multiple companies across different sectors to validate and compare the findings. Investigating the long-term impacts of salary increments on employee performance and retention would also be valuable. Further studies could employ mixed methods to gain deeper insights into employee satisfaction and motivation, integrating qualitative data from interviews or focus groups to complement the quantitative data.

CONCLUSION

The study underscores the significant achievements and robust internal dynamics of Guangzhou Wangming Water Joy Design Co., Ltd., established in 2006 and now a leader in China's

L-RTM technology water park equipment sector. Expanding from a national enterprise to a global contender, the company has made its mark in over 30 countries, emphasizing its international prowess and strategic growth. Analysis of the company's workforce demographics reveals a predominance of experienced males aged 36 to 45, highlighting a focus on seasoned professionals and ongoing professional development linked directly to salary progression. This reflects a mature, growth-oriented work environment where skill enhancement is strategically aligned with compensation. The company's comprehensive employee welfare approach extends beyond financial compensation, focusing on health, wellness, and work-life balance, thus fostering a supportive and productive workplace. Such practices not only enhance job satisfaction and retention but also position the company as a benchmark for industry peers. This thorough examination provides actionable recommendations to enhance operational efficiency and competitiveness. Suggestions include integrating the company's rich history into employee programs to build a stronger corporate identity, promoting gender diversity to enrich the corporate culture, updating training programs to maintain a competitive edge, and expanding welfare benefits to boost satisfaction and retention. Implementing continuous feedback mechanisms can help the company stay adaptive and responsive to both employee needs and market changes. By applying these insights, Guangzhou Wangming Water Joy Design Co., Ltd. can continue to lead and innovate, serving as a model for similar companies within the industry aiming to foster a progressive and inclusive organizational environment.

AUTHOR CONTRIBUTIONS

L. Yu was responsible for data collection, writing, and conceptualization of the research. L. Yu also handled all aspects of writing and data collection for the paper. A.R. Santos served as the technical writing guide and advisor for the dissertation, improved the literature review, revised the manuscript to a publishable standard, and processed the publication.

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CONFLICT OF INTEREST

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

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ABBREVIATIONS (NOMENCLATURE)

CPI	Consumer Price Index
FDI	Foreign Direct Investment

GDP	Gross Domestic Product
HR	Human Resources
IBMC	International Business Machines Corporation
IT	Information Technology
L-RTM	Light-Resin Transfer Molding
R & D	Research and Development
ROI	Return on Investment
SOEs	State-Owned Enterprises
WM	Weighted Mean
WMWJD Co., Ltd.	Guangzhou Wangming Water Joy Design Co., Ltd.
WTO	World Trade Organization

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ORIGINAL RESEARCH PAPER

Exploring individual and organizational contributors to workplace deviant behavior

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ABSTRACT

BACKGROUND AND OBJECTIVES: Workplace deviant behavior, as a manifestation of employee conduct, can exert adverse effects on an organization, posing challenges to its overall functioning and well-being. Understanding the underlying mechanism is essential in offering insights to enhance risk mitigation and promote a positive organizational culture for sustained success. Therefore, the study on workplace deviant behavior is important because it addresses both practical and theoretical concerns crucial for organizations' functioning and success. Additionally, it helps in understanding the dynamics of employee behavior, developing effective management strategies, and promoting a productive and ethical workplace environment. The novelty and originality of this research lie in its integration of these three variables to understand their combined impact on workplace deviant behavior. This approach provides a more detailed and nuanced understanding of the factors contributing to deviant behavior, allowing for more effective mitigation strategies.

METHODS: This study aims to examine the impact of employee personality, organizational culture, and perceived organizational support on workplace deviant behavior among 370 employees at Human Development Agencies in Indonesia. Data were collected using questionnaires and analyzed using IBM SPSS version 26.

FINDINGS: The results showed a significant negative correlation between employee personality traits, such as extraversion (t-value = -2.400, p-value = 0.019, $p < 0.05$) and agreeableness (t-value = -2.170, p-value = 0.034, $p < 0.05$), and organizational culture (t-value = -2.386, p-value = 0.020, $p < 0.05$). However, perceived organizational support only moderates organizational culture's influence on workplace deviant behavior, not employee personality traits. The study suggests strategies to prevent and mitigate its negative effects on organizations.

CONCLUSION: The study recommends the implementation of conducive policies and practices to efficiently handle these behaviors. Moreover, this study enhances comprehension of workplace deviant behavior and provides pragmatic suggestions for effectively managing and averting such conduct within organizations. This highlights the significance of creating supportive policies and practices that specifically address organizational culture and support mechanisms to effectively reduce workplace deviant behavior.

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INTRODUCTION

The primary objective of modern management is to uphold the organizational culture, business vision, workplace environment, productivity, and efficiency by deterring employees from deliberately contravening the organization's established norms, values, relationships, culture, and overall welfare (Agwa, 2018). As one of many workplace behaviors, Workplace Deviant Behavior (WDB) refers to any form of misconduct, rudeness, counterproductive actions, or wrongdoing that occurs within an organization (Abdullah and Marican, 2016; Mao, 2022; Rehan et al., 2021; Sackett, 2002). It is voluntary and might threaten the organization's or its members' well-being (Kalemci et al., 2019). Research in behavioral science has identified crucial factors that contribute to WDB, such as organizational culture (Wang et al., 2018) and evolving socio-technological factors (Malik, 2021). WDB has significant implications for comprehending the intricacies of organizational dynamics and effectively tackling associated challenges. Therefore, an anticipatory approach to understanding and addressing WDB is essential for a resilient and thriving organization. Critical elements of WDB in behavioral science encompass adverse outcomes, proactive measures, interventions, and their influence on occupational effectiveness (Brice and Rupp, 2015; Kalemci et al., 2019; Rogoan, 2009). Employee personality and perceptions of organizational justice significantly influence the likelihood of engaging in WDB (Berry et al., Sackett, 2007). Certain individual traits, such as immaturity or instability, a propensity for personal gain, and impatience, elevate the risk of participating in WDB (Sackett, 2002). On the other hand, prior studies found that other than individual personality differences, the organizational environment is also the top predictor of WDB (Mitchell and Ambrose, 2007; O'Neill and Hatings, 2011). Multiple studies have consistently demonstrated that WDB can result in conflicts within the workplace. These conflicts are often influenced by individuals' perceptions of stress and conflicts between work and family life (Malisetty, 2016). Furthermore, these negative perceptions are linked to a lack of fairness and equity within the organization. WDB may arise as a consequence of familial dynamics (Dede, 2020), organizational deviance, and organizational culture (Wang et al., 2018). Chirasha (2012) emphasized

the widespread occurrence of WDB and its detrimental effect on organizational performance. The author stressed the importance of management participation and the implementation of ethical programs. By acknowledging the critical significance of management involvement and ethical initiatives, organizations can actively foster an atmosphere that deters deviant conduct, thereby protecting their culture, productivity, and overall achievements. This research emphasizes the critical nature of addressing WDB as a strategic priority to cultivate a work environment founded upon integrity, fairness, and sustainable success, particularly in an era where organizational resilience is of the utmost importance. This study examines the influence of WDB on the Human Development Agency, a local government agency in charge of public service operations. The research uncovers that the agency is marred by WDB, including tardiness, extended breaks, misuse of organizational email or internet resources for personal matters, and absenteeism. WDB is displayed by individuals or groups who are seen as deviant and violate the organization's norms, policies, or regulations, which can put the organization and its members at risk (Robinson and Bennett, 1995). Certain employees depart from work ahead of schedule due to pressing personal affairs. Rushna (2021) contends that the concept and terminology surrounding misbehavior in the context of WDB have yet to be thoroughly studied, and there is a lack of consensus regarding its scope. To accurately predict WDB, it is necessary to conduct a thorough investigation that focuses on personality domains and considers the impact of personality differences (Luca et al., 2019). Moreover, Tian and Guo (2023) propose that previous research on WDB should be reassessed to align with the present requirements of business management. Organizations should understand WDB and try to reduce its occurrence. This study investigates the correlation between employee personality and organizational culture by incorporating Perceived Organizational Support (POS) to gain extensive comprehension. When employees feel supported, they are more likely to engage in positive behaviors and less likely to engage in deviant behaviors (Abdullah et al., 2021). Kim and Jung (2022) have shown that organizational culture plays a crucial role in reducing deviant behavior in the workplace. However, there is a need to explore

how employee personality traits like extraversion and agreeableness interact with organizational culture to impact deviant behavior. This gap highlights the need for studies on the moderating effects of these traits on the relationship between organizational culture and deviant behavior. An optimistic organizational culture can improve the welfare of employees (Caesens *et al.*, 2016; Mohammadi, 2020), while a strong perception of organizational support can decrease WDB (Chen *et al.*, 2016). Nevertheless, more research is needed on the role of POS as a moderating variable, indicating the necessity for further investigation to comprehend its impact on WDB. The purpose of this research is to investigate the relationship between these factors and their influence on deviant behavior in the workplace. The study provides insights into how these factors contribute to or mitigate deviant behavior and whether perceived organizational support moderates this relationship, ultimately helping organizations develop strategies to reduce such behavior and improve workplace performance like guiding organizations in enhancing positive behavior and employee well-being, as well as recommending the implementation of a code of ethics by the government to ensure compliance with mandatory regulations by civil servants. The research also offers insights for developing more efficient strategies to enhance employee well-being and guarantee adherence to regulations. Therefore, this study examines the impact of employee personality, organizational culture, and POS on WDB among employees. This study was conducted using a survey method by distributing questionnaires to employees of the Human Development Agencies in Indonesia from June 7 to August 29, 2023. This research was conducted because it is effective for the Human Development of Purwokerto Regency, Indonesia. The agency is marred by WDB, which includes delays, extended breaks, misuse of organizational email or internet resources for personal matters, and absenteeism. Then, a more detailed understanding of these factors is carried out to reduce the impact on DWB. Through empirical analysis and theoretical synthesis, this research aims to contribute actionable insights for organizational leaders and human resource professionals seeking to cultivate a positive organizational climate that promotes ethical behavior and sustains long-term organizational success. A review of the information

provided shows that the researcher is intrigued by a study titled "Investigating the factors contributing to workplace deviant behavior at the individual and organizational levels."

Literature review

Individuals employ a multifaceted amalgamation of psychological characteristics that constitute their personality to conform to their surroundings (Larsen and Buss, 2005). The Big Five Personality Traits Model proposed by psychologist Goldberg (1982) examines different types of traits through five dimensions: openness, conscientiousness, extraversion, agreeableness, and neuroticism. Another foundational notion to research on WDB is the self-efficacy theory, which describes how employees perceive their ability to control their emotions, thoughts, and actions to attain their objectives (Zimmerman *et al.*, 1992). Higher levels of emotional intelligence tend to have innovative work behavior and higher work quality, including communication, collaboration, and problem-solving skills (Tajpour *et al.*, 2018). The effectiveness of this self-regularity is crucial for regulating behavior and ensuring adherence to appropriate self-sanctions (Rehan *et al.*, 2021). Following the Action Theory (Zohar and Luria, 2004), those who are concerned that undesirable conduct will sabotage their potential ought to abstain from such conduct and maintain a diligent work ethic. Furthermore, group value theory identifies an individual's belongingness and how a negative attitude can promote agreeableness and WDB (Lind and Lissak, 1985). When an individual's values and norms are not aligned with those of their organization or workgroup, they may engage in deviant behaviors to assert their identity and maintain their self-esteem. This can include behaviors such as sabotage, theft, or harassment (Puspita and Zakiy, 2020). Personality traits have been found to significantly predict WDB and incivility, highlighting the importance of understanding and addressing these traits in the workplace (Abdullah *et al.*, 2021). In essence, the intricate interplay between psychological characteristics, such as those delineated in the Big Five Personality Traits Model and the self-efficacy theory, underscores the nuanced dynamics shaping individual behavior within the workplace (Udin and Yuniawan, 2020), ultimately emphasizing the imperative of fostering a conducive environment that nurtures positive traits while mitigating potential

triggers for WDB. In the realm of behavioral science, organizational culture encapsulates shared values, beliefs, and perceptions among employees, shaping their attitudes and behavior (Bakhri *et al.*, 2018; Maryati *et al.*, 2019; Tsai, 2011). The effective management of organizational culture is underscored in applied behavioral science, recognizing visible elements such as dress code and technology used as influential factors (Chitra *et al.*, 2018; Dharshini *et al.*, 2023). Organizational cultures prioritizing individual achievement over teamwork may inadvertently encourage WDB for personal gain (Kalemci *et al.*, 2019). The emergence of WDB is linked to internalizing low organizational culture values, highlighting the pivotal role of organizational climate in setting the tone for individual conduct (Braje *et al.*, 2020; Tian and Guo, 2023). A positive organizational climate can reduce the negative effects of workplace incivility on deviant behavior (Zahid and Nauman, 2023). Conversely, fostering a positive organizational culture proves instrumental in mitigating occurrences of WDB. Grounded in the Person-Organization Fit theory and the Job-Fit concept, the alignment of vision, ideas, values, and ethics between employees and organizations is essential for cultivating commitment and engagement (Cable and DeRue, 2002; Edwards and Cable, 2009). A culture that supports employee development can enhance Person-Organization Fit and job performance (Zhang *et al.*, 2021). This alignment not only promotes a positive organizational culture but also establishes a foundation for employees to feel connected to the broader responsibilities of the organization. Viewing these dynamics through the lens of the Social Cognitive Theory underscores the influence of individual personalities on the interpretation and response to organizational contexts (Bandura, 1978). In this context, organizational climate, perceived as an uncontrollable environmental condition, significantly influences individual behavior (Zohar and Luria, 2004). Job-related factors such as workload, job hazards, and interpersonal discrimination can significantly impact employee engagement and behavior. Employee engagement is critical in determining the extent to which employees are motivated and committed to their work (Oladejo and Kareem, 2019). Recognizing employee behavior as a reflection of their personality trait and self-reflection ability reinforces decisions to avoid involvement in deviant conduct, safeguarding the organizational integrity. In conclusion, the

intricate interplay between organizational culture, individual values, and behavioral dynamics necessitates a thoughtful and strategic approach to management, emphasizing alignment and fostering a positive culture that discourages WDB while promoting organizational well-being. In this context, prioritizing the organization's role in supporting its members becomes paramount. POS, defined as an individual's perception of the organization's valuation of employee contributions and concern for their well-being, plays a pivotal role in shaping the relationship between employees and their superiors, influenced by the social exchange theory (Eisenberger *et al.*, 1986). The impact of POS extends to its influence on employees' WDB, as evidenced by studies that reveal its role in weakening the negative effect of WDB on job performance (Fridslan *et al.*, 2023; Tian and Guo, 2023). A crucial facet emerges – when employees perceive support, their commitment increases and the likelihood of engaging in WDB in response to stress or tension diminishes (Eisenberger and Stinghamber, 2011). Aligned with these insights, the Conservation Resource Theory suggests that feelings of ignorance, lack of support, and exclusion within the organization create dissatisfaction and complexity in employees' positions. This mental state hampers their efforts to meet performance requirements and intensifies the pressure on their tasks due to a perceived need for more knowledge (Clercq *et al.*, 2019). Further reinforcing this perspective, a study in the hotel industry identified organizational factors, including an unethical climate, high job demand, a lack of supervisory support, and trust issues, as influencing WDB among employees (Yekinni, 2019). In conclusion, recognizing and fostering POS are crucial to mitigating WDB. Organizations that actively prioritize the well-being and contributions of their members diminish the negative impact of WDB on performance and contribute to a positive work environment. As we navigate the complex interplay between organizational dynamics and employee behavior, focusing on POS is critical in promoting a harmonious and productive workplace.

Hypotheses development

Relationship between employee personality and WDB

The intricate landscape of WDB requires a proactive approach to understanding and addressing

its contributing factors. Enhancing workforce productivity is contingent upon employees cultivating a robust personality and actively participating in talent development. Within this context, two influential determinants of WDB emerge employee personality and perceptions of organizational justice. [Salgado \(2002\)](#) establishes a connection between the Big Five Personality factors and counterproductive work behavior, encompassing actions like absenteeism, premature departure, and errors in the work process. This research focuses on two dimensions of the Big Five Personality traits: Extraversion and Agreeableness. Employees with extraversion personalities tend to be sociable, attentive, generous, and credulous, especially toward their superiors. They tend to keep themselves busy, display enthusiasm, and possess strong communication skills, creating an impression of being energetic, friendly, and ambitious. On the other hand, employees with agreeableness personalities tend to trust others readily and seldom suspect hidden motives or intentions in their colleagues. They are generally pleasant, easy to get along with, wise, friendly, optimistic, generous, helpful, and willing to compromise ([Rothmann and Coetzer, 2013](#)). Research has shown that personality traits, including extraversion, conscientiousness, agreeableness, neuroticism, and openness to experience, are correlated with counterproductive work behavior, with agreeableness having a negative correlation ([Maqsood et al., 2021](#)). Flowingly, research conducted by [Bolton et al. \(2010\)](#) and [Kozako et al. \(2013\)](#) suggests that individuals with lower levels of agreeableness are more prone to engaging in aggressive behavior and conflicts, making them more likely to commit deviant acts. Conversely, those with higher levels of agreeableness are less inclined to commit deviant acts or become involved in WDB. Numerous prior research has studied the implications of employee personality on WDB. Employee agreeableness was a significant predictor of workplace deviance, with higher agreeableness scores associated with lower levels of deviance ([Zhuang et al., 2023](#)). When employees with high extraversion perceive high organizational support, they are less likely to engage in deviant behaviors. This suggests that extroverted individuals are more likely to channel their energy into positive behaviors when they feel supported by their organization ([He and Li, 2019](#)). In conclusion, understanding and addressing the intricate landscape

of WDB is crucial for fostering a resilient and thriving organizational ecosystem. Given the facts presented above, the hypothesis proposed for this study is:

H1a: Employees' extraversion personality hurts WDB.

H1b: Employees' agreeableness personality hurts WDB.

Organizational culture and WDB

WDB encompasses actions by organizational members that violate rules and challenge the established organizational culture, posing risks to both the organization and its members ([Robinson and Bennett, 1995](#)). Mitigating WDB within the workplace requires employees to align with specific organizational cultures. Therefore, cultures should be grounded in fundamental ethical values ([Sinclair, 1993](#)). Organizational cultures that tolerate unethical conduct, lack proper supervision, and lack transparency are more prone to fostering WDB. Conversely, a well-defined and consistent organizational culture plays a pivotal role in fostering a healthy work environment and diminishing the likelihood of WDB. Organizational culture serves as a key catalyst for WDB within the workplace. Studies reveal a noteworthy inverse relationship between organizational culture and WDB ([Alias et al., 2018](#)), emphasizing the influential role of an innovative culture in shaping employee conduct ([Cohen and Ehrlich, 2019](#); [Mangahas, 2023](#)). The fluctuations in organizational culture wield a substantial impact on the manifestation of WDB among employees ([Noermijanti et al., 2021](#)). Consequently, an enhancement in organizational culture is intricately linked to a reduction in instances of WDB. To be accepted and recognized in a particular environment, people must conform to the dominant culture ([Udin, 2023](#)), which shapes personalities. Conforming to universally accepted standards that guide behavior is essential to developing positive behavior and mindsets.

Therefore,

H2: Organizational culture has a negative consequence on WDB.

POS, employee extraversion personality, and WDB

POS refers to an individual's perception of the organization's positive or negative attitude towards them, including recognizing their contributions and

showing concern for their well-being (Eisenberger et al., 1986). Employees are more inclined to exhibit employer loyalty and adherence to workplace regulations when they perceive that the organization offers sufficient support (Astuty and Udin, 2020). Joy and Balu (2016) observed a substantial inverse correlation between counterproductive work behavior and organizational support. Research has examined the correlation between POS and personality traits, with extraverted personality, and POS has been studied in the context of job satisfaction and organizational citizenship behavior. Zhou et al. (2023) indicate that extraversion and other personality traits, such as conscientiousness and agreeableness, are positively related to POS. It plays a pivotal role in the effective attainment of organizational goals (Onuoho, 2013). While employee personality can impact WDB in the workplace, the presence of organizational support can act as a mitigating factor, offsetting the potential negative effects of a deviant personality. A robust perception of organizational support correlates with a decreased likelihood of WDB occurring within the workplace, and conversely, a weaker perception is associated with a higher incidence of such behavior. The anticipated moderation of employee personality's influence on WDB is achieved through the implementation of transparent policies, including well-defined ethical and behavioral guidelines.

H3: POS moderates the influence of employee extraversion personality on WDB.

POS, employee personality agreeableness, and WDB

Following the previous discussion, employees who possess agreeableness as a personality trait are inclined to exhibit friendliness and exhibit less engagement in WDB. This occurs as they perceive their organization as being supportive and fostering loyalty. Employees who possess a strong inclination towards agreeability are more likely to experience a sense of connection with their organization and demonstrate adherence to established rules and norms. In contrast, employees who have lower agreeableness are more prone to engaging in WDB (Chang and Smithikrai, 2010). Studies employing the social exchange theory on employees' commitment have demonstrated that the interplay between POS and employee agreeableness can significantly impact workplace behavior (Hanif and Siddiqui,

2020). Thus, it is hypothesized that both personality traits substantially impact WDB.

H4: POS moderates the influence of employee agreeableness personality on WDB.

POS, organizational culture, and WDB

The state of organizational culture has a significant impact on WDB, as it encompasses the organization's shared beliefs and values that contribute to its employees' well-being (Rhoades and Eisenberger, 2002). An affirmative organizational culture amplifies employee dedication and adherence to standards and regulations. Conversely, unfavorable or detrimental organizational cultures can result in employees breaching norms and regulations. Effective POS enables employees to fully utilize their abilities and prevents behaviors that could undermine employee and organizational performance. A positive correlation exists between organizational culture and POS, as a strong organizational culture can result in improved employee engagement and job satisfaction (Nurcholis and Budi, 2020). The presence of a negative organizational climate and workplace conflict hurts WDB. However, this negative influence can be mitigated by the perception of organizational support, which acts as a mediator (Fridslan et al. 2023).

H5: POS moderates the influence of organizational culture on WDB.

MATERIALS AND METHODS

Sample

The sampling technique in this research is nonprobability sampling with a saturated sampling type, which means all populations, as many as 370 members, are used as samples to ensure the researcher obtains reliable and comprehensive data. This technique was chosen because, given that the Human Development Agency operates as a government regulatory entity with standards that are uniformly applied nationally, this sample is considered to be representative of the broader organizational culture, so it is desirable to make generalizations with very small or substantial errors.

Instruments

Before distributing the questionnaire, the instrument's author tested its validity by

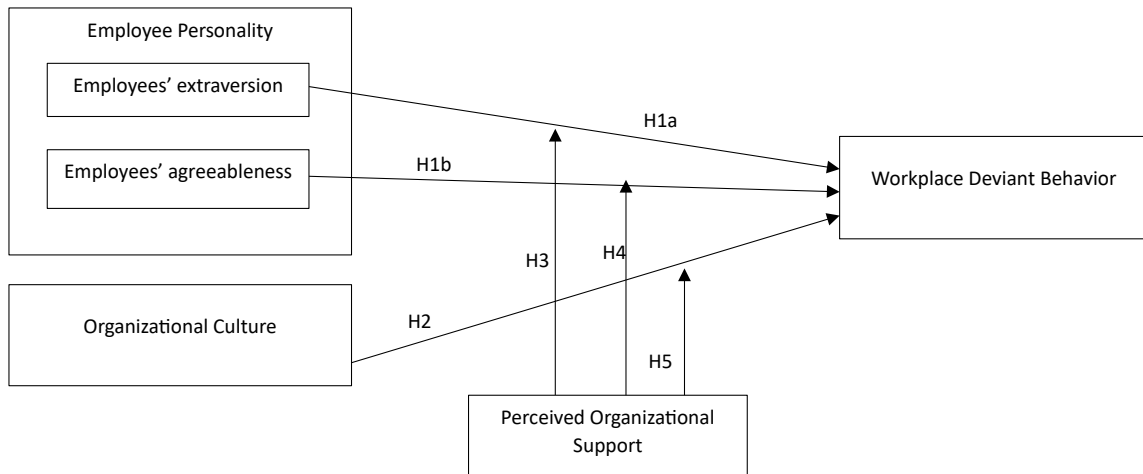


Fig. 1: Research framework

administering it to 10 respondents. The average value and Cronbach alpha were valid, indicating the instrument's reliability and effectiveness in measuring the intended construct. This suggests that the instrument is a robust tool for assessing the construct of interest, and its results can be trusted to provide accurate information. The data were gathered by directly distributing a questionnaire sheet containing closed-ended questions to the participants. The ordinal measurements of the personal personality questionnaires were utilized to determine the relative order or ranking of the research variables' items. The participants were requested to indicate their level of agreement or disagreement with specific statements using a Likert scale from 1 to 5, consisting of the following options: "strongly disagree," "strongly agree," "undecided," and "strongly agree."

The procedure of data analysis

Before the statistical analysis, classical assumption testing was performed to ensure that the regression model obtained was accurately estimated, consistent, and unbiased. To evaluate the H1a, H1b, and H2 hypotheses, the author employed basic linear regression analysis to quantify the degree of association between the independent

and dependent variables. The objective was to forecast the dependent variable's value based on the independent variable's value. To examine hypotheses H3, H4, and H5, the author employed a moderated linear regression analysis to assess whether the moderator influenced the magnitude of the association between the independent and dependent variables.

RESULTS AND DISCUSSION

Table 1 presents a descriptive analysis of key variables in the study, encompassing 370 respondents. The mean extraversion score of 3.539 indicates a relatively high level, suggesting respondents' overall outgoing and sociable tendencies. In contrast, the mean agreeableness score of 3.194 suggests a moderate level, reflecting a balanced degree of empathy and cooperation within the sample. This analysis highlights the diverse interplay of personality traits, with a tilt toward higher extraversion and a moderate level of agreeableness among the studied group. Furthermore, with a mean of 4.327, the organizational culture is classified as very high. This indicates a generally positive and strong organizational culture within the studied context.

Table 2 presents the outcomes of the validity tests for key study variables. All variables demonstrate validity (significance value ≤ 0.05). This indicates that the measurement instruments employed effectively capture and assess the intended constructs for each variable, reinforcing the reliability and accuracy of the data collected.

Table 3 outlines the reliability test outcomes where all key variables exhibit acceptable reliability with Cronbach's Alpha scores ranging from 0.635 to 0.875. These values surpass the threshold acceptance value of 0.600, affirming the internal consistency and dependability of the measurement instruments used for each variable. The results underscore the robustness and reliability of the data collected in the study.

Based on the simple linear regression test (see Table 4), the t-values, ranging from -2.170 to -2.400, and the associated significant values ($p < 0.05$) indicate that these variables exert a statistically significant influence on the response variable. The negative t-values suggest an inverse relationship,

while the significance underscores the influential impact of these predictors on the studied outcome, contributing valuable insights to the understanding of the observed relationships.

Table 5 outlines the results of moderated regression analysis, in Equation I, Employee Extraversion Personality initially demonstrates a significant negative impact ($p = 0.017$), which becomes non-significant in Equation II ($p = 0.982$), suggesting no substantial moderation effect. Similarly, Employee Agreeableness Personality exhibits an initially significant negative effect ($p = 0.009$), but this effect decreases as the interaction term is added ($p = 0.630$). It is worth mentioning that Organizational Culture exhibits a marginally significant negative effect in Equation I ($p = 0.077$), but subsequently transforms into a substantially positive impact in Equation II ($p = 0.039$), suggesting the presence of a moderating influence. The results of this study highlight the intricate interplay between POS and the associations between personality traits and WDB. As a result, these findings significantly

Table 1: Descriptive analysis of respondents

Variable	N	Grand Total		
		Mean	Criteria	Std. Dev
Employee extraversion personality	370	3.539	High	1.090
Employee agreeableness personality	370	3.194	Moderate	1.734
Organizational culture	370	4.327	Very high	0.817
POS	370	3.918	High	1.015
WDB	370	1.322	Very low	0.527

Table 2: Validity test results

Variable	N	Description
Employee extraversion personality	370	Valid
Employee agreeableness personality	370	Valid
Organizational culture	370	Valid
POS	370	Valid
WDB	370	Valid

Table 3: Reliability test results

Variable	Cronbach's Alpha	Acceptance Value	Description
Employee extraversion personality	0.635	0.600	Reliable
Employee agreeableness personality	0.649	0.600	Reliable
Organizational culture	0.875	0.600	Reliable
POS	0.866	0.600	Reliable
WDB	0.719	0.600	Reliable

Table 4: Simple linear regression analysis

Variable	t-value	Significant value	Description
Employee extraversion personality	-2.400	0.019	Influential
Employee agreeableness personality	-2.170	0.034	Influential
Organizational culture	-2.386	0.020	Influential

Table 5: Moderated regression analysis

Variable	Equation I		Equation II		Description
	t-value	Significant value	t-value	Significant value	
Employee extraversion personality	-2.463	0.017	-0.023	0.982	No effect
POS	-1.080	0.284	0.158	0.875	
Employee agreeableness personality	-2.223	0.009	0.484	0.630	No effect
POS	-1.043	0.549	0.624	0.535	
Organizational culture	-1.802	0.077	2.109	0.039	Influential
POS	-0.445	0.658	2.455	0.017	

contribute to the body of knowledge regarding these complex relationships.

The study reveals a noteworthy correlation between employees' extraversion personalities and a significant negative impact on WDB. This suggests that individuals with higher extraversion levels are less prone to engaging in deviant conduct within the workplace. Research indicates that extroverts leverage social support networks to boost their energy levels during stress, employing effective coping mechanisms to navigate stress and exhaustion (Bakker *et al.*, 2006; Roesch *et al.*, 2006; Darr and Johns, 2008). Notably, earlier studies by Hastuti *et al.*, (2017) have also established a significant inverse correlation between employee extraversion and WDB, aligning with and reinforcing the current findings. The impact of an employee's agreeableness personality on WDB is also significant, revealing a negative correlation. Individuals with a higher degree of agreeableness are less likely to engage in WDB. This finding resonates with Kozako *et al.*, (2013), who similarly identified agreeableness as a deterrent to WDB. Notably, individuals exhibiting self-reported agreeableness, characterized by kindness, care, friendliness, and courtesy, tend to avoid harmful actions at work, aligning with the concept of prosocial behavior, as highlighted by Bennett and Robinson (2000). This inclination is rooted in their agreeable identity, as going against it

would contradict their inherently benevolent nature. Furthermore, a recent meta-analysis emphasizing agreeableness as the highest predictor of workplace deviance and future job performance (Luca *et al.*, 2019) corroborates the study's findings. The research supports the group value theory, affirming that individuals with agreeableness characteristics exhibit empathy, patience, trustworthiness, and a strong sense of belonging to the group, thereby constraining deviant attitudes. Another study grounded in the Big Five personality traits theory asserts that while neuroticism poses a risk factor for deviant actions in the context of emotional tiredness, agreeableness, and extroversion serve as protective qualities (Golparvar *et al.*, 2017). WDB is significantly influenced by organizational culture, demonstrating a notable negative correlation. A positive organizational culture appears to act as a mitigating factor, reducing the occurrence of WDB. Aligning with the results reported by Mabruroh (2021), our findings reveal a negative correlation between organizational culture and WDB. However, this contradicts the conclusions drawn by Nainggolan (2019) and Rizal *et al.*, (2019), which suggested a positive influence of organizational culture on WDB. Additionally, Mohammed *et al.*, (2023) conclude that a high-commitment human resource management approach can enhance organizational engagement, thereby lowering WDB

directed at the organization. Careful communication and implementation are crucial for organizations to secure employee support for such practices. A cross-cultural study in India and the USA by [Narayanan and Moon \(2022\)](#), grounded in social cognitive theory, suggests that a highly collectivist organizational culture reduces employee engagement in WDB. Moreover, [Wimbush and Shepard \(1994\)](#) propose the predictive value of an organization's ethical climate in anticipating unethical and unproductive behavior, a concept reinforced by [Peterson's \(2002\)](#) research utilizing the ethical climate questionnaire, which documented multiple correlations between organizational climate and various forms of WDB. The relationship between WDB and organizational culture was found to be moderated by POS. Prior research has consistently shown a positive correlation between organizational citizenship behaviors and POS ([Dalal, 2005](#); [Gruys and Sackett, 2003](#)). The conventional interpretation suggests that individuals who believe their contributions are valued and perceive organizational concern for their well-being are more inclined to anticipate favorable treatment from the organization. Contrarily, WDB demonstrates a negative correlation with POS, as observed by [Nair and Bhatnagar \(2011\)](#). [Iqbal et al., \(2015\)](#) present an alternative perspective that emphasizes the critical role of oversight and organizational support in fostering a positive workplace atmosphere. Employees who feel a sense of belonging within the organization tend to prioritize organizational objectives and core values, displaying a genuine concern for their professional growth. Furthermore, recognizing supervisors as representatives of the organization underscores the significance of their supportive behavior in shaping a positive organizational perception among subordinates. The main findings of this research highlight the role of individual factors such as personality traits, emotions, and situational factors in contributing to deviant behavior in the workplace, such as employee agreeableness and extraversion. When employees perceive their organization as supportive, they are more likely to engage in cooperative behavior and maintain positive relationships, reducing the likelihood of deviant behavior. The positive effects of friendly attitudes and extraversion in reducing deviant behavior will be even more significant in such an environment.

Not only that, but a positive organizational culture can also reduce deviant behavior in the workplace by fostering a sense of belonging, trust, and shared values among employees. This leads to increased job satisfaction, organizational commitment, and reduced turnover. The POS role can help reduce the negative impact of deviant behavior by supporting a supportive work environment. This can be achieved by fostering a culture of collectivism, power distance, and paternalism, reducing levels of deviant behavior. This research can potentially advance our understanding of workplace deviant behavior significantly and contribute to developing more effective strategies to reduce it. This research's methodological and practical contributions can also enhance the statistical community's knowledge and tools for analyzing and addressing workplace problems by developing more effective models and interventions to address these critical issues, ultimately improving organizational performance and employee well-being.

CONCLUSION

The research emphasizes the importance of considering multiple factors, including personality traits, organizational culture, and perceived organizational support, to understand and mitigate deviant workplace behavior. This study has revealed significant correlations between individual personality traits, organizational culture, and WDB. The demonstrated negative influence of extraversion and agreeableness on subjective well-being (WDB) is consistent with prior studies, underscoring the crucial significance of these characteristics in cultivating a favorable and cohesive work environment. Theoretically, this study highlights the importance of personality traits, particularly compassion and extroversion, in understanding deviant behavior in the workplace, which supports the idea that individual differences play an important role in shaping behavior. Moreover, our research adds to the increasing amount of evidence supporting organizational culture's impact on counterproductive work behavior (WDB), highlighting the intricate dynamics involved. The moderation effect of POS highlights the significance of cultivating a workplace atmosphere that promotes employees' sense of worth, assistance, and alignment with organizational objectives,

thereby reducing the likelihood of WDB. This study enhances our comprehension of the complex interaction among personal attributes, company elements, and job-related conduct, offering valuable perspectives for organizations aiming to foster a salubrious and efficient work atmosphere. Organizations should focus on creating a positive organizational culture that encourages a supportive environment and fosters positive relationships among employees. They should consider the role of personality traits in shaping employee behavior and develop strategies to promote positive characteristics. Performance management systems should be designed to recognize and reward positive behavior rather than just focusing on productivity metrics. Organizations must also prioritize providing perceived organizational support to employees to reduce deviant behavior. Nevertheless, it is crucial to recognize the limitations of this study. The significance of the research may be restricted to the particular context of the regional personnel and human development, but it is generalizable to a similar type of organization. Therefore, differences in organizational structures or cultural settings could produce divergent outcomes. Moreover, the study relies on self-reported data, which can the dependence on data provided by respondents themselves introduces the possibility of response bias, and the study's cross-sectional design restricts the ability to establish a cause-and-effect relationship, which does not allow for examining temporal relationships between variables. Although there are limitations, the acquired insights contribute to the broader knowledge base on organizational behavior and establish a basis for future research efforts in this dynamic field. Future research can conduct a longitudinal study to examine the temporal relationships between variables and the dynamics of deviant behavior over time. First, control for other factors influencing deviant behavior, such as job satisfaction, work-life balance, and leadership style. Lastly, studies in diverse organizational settings and populations should be conducted to enhance generalizability and ensure that the findings are not limited to specific contexts. These future research directions can further our understanding of the complex relationships between employee personality, organizational culture, and deviant behavior, ultimately informing the development of

effective interventions to reduce deviant behavior and improve organizational performance.

AUTHOR CONTRIBUTIONS

D. Daryono performed the conceptualization, literature review, and wrote the original draft. R.S. Gunawan supervised the research and assisted in the collection of data as well as analysis. The corresponding author, U. Udin, managed the visualization, performed the validation tests, and reviewed as well as edited the manuscript.

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CONFLICT OF INTEREST

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

PUBLISHER'S NOTE

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ABBREVIATIONS (NOMENCLATURE)

WDB	Workplace Deviant Behavior
POS	Perceived Organizational Support

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ORIGINAL RESEARCH PAPER

On the concept of Urban Mutations: Urban research bibliography with an objective approach

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ABSTRACT

BACKGROUND AND OBJECTIVES: Urban studies, as a field of research, often encounter a certain strictness in determining precise concept definitions. This latter represents the epistemological underpinnings which are considered as the base of their theoretical foundation. Such difficulty in pinpointing an accurate definition is particularly evident in the varying terminology used to describe urban phenomena, ranging from terms like “mutation”, “change”, “transformation”, “gentrification”, and “transition”. Each term carries its own nuances and implications, reflecting the diverse perspectives within the field. In this context, the primary objective of this paper is to evaluate scientific publications within the realm of urban studies to conduct a comprehensive analysis, assessing the frequency and contextual significance of the aforementioned terms in articles about urban mutations.

METHODS: The article framework involved conducting a bibliometric review of the literature using the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” framework. The first 5595 documents were identified in the Scopus database. After a process of inclusion and exclusion, only 1768 articles spanning from 1981 to 2023 were extracted. These data were then processed using CiteSpace to analyze cooperative networks. This analysis encompasses three key dimensions: Citation, Co-citation, and Co-occurrence.

FINDINGS: Few authors used bibliometrics to address urban mutations comprising only 32 articles, published between 2016 and 2023. The citation analysis revealed Salvati Luca as the most co-cited author, and the United Kingdom as a top contributing country with 287 citations and a centrality value of 0.35. Furthermore, the co-citation analysis ranked the cluster labeled “Urban Change” at the top with 501 citations and 0.917 for silhouette. Meanwhile, the most frequently co-cited journal is “Urban Studies”, boasting 602 co-citations. For the co-occurrences, the term “Urban Change” ranked second in strength burst (35.13), and first in centrality (0.41). The term “Urban Transformation” holds the 19th position with a centrality score of 0.05. However, this latter ranks 3rd in the classification by citation (384). “Urban Change”, then, comes in at the 5th position with 211 citations. The term “Urban Mutation” did not appear in any analysis. “Urban Change” and “Urban Transformation” stand out as the most commonly used. Most references are cited in English.

CONCLUSION: Scientometric analysis is essential for identifying potential correlations within the literature. This helps urban studies utilize discipline-specific terminology, thereby ensuring the rigor and integrity of its concepts. Moreover, this study could be used for other comparisons with different databases, such as Web of Science, Dimensions, and PubMed.

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INTRODUCTION

Cities, as constantly evolving dynamic entities, undergo a profound transformation as a result of Urban Mutations. These latter are multidimensional transformations that affect all aspects of urban life, starting from the city morphology to the socioeconomic, political, environmental, and cultural structures (Lacoste, 2012). Mutation, as a term, originates from the Latin word “mutation” or mature and is defined by the Oxford English Dictionary as “a change in the form or structure of something”, (“Mutation”, n.d., para. 2), and as “change” by the Merriam-Webster dictionary, (“Mutation”, n.d., para. 1). The concept of urban mutation refers to all the significant transformations that cities undergo over time. Urban Mutation is the profound physical, social, and organizational transformations that cities undergo, affecting various aspects of urban life, shaping the urban landscape, and considerably influencing their inhabitants’ lifestyles and urban reality, which have “diverse forms” and “multiple meanings” (Ledrut, 1984). These transformations can be gradual or brutal (Louis & Balandier, 1970) and affect various aspects of urban life, qualifying them as a considerable transition from one form to another (Choay & Merlin, 2010). These urban mutations are linked to deep semantic, societal, and cultural ruptures, giving rise to totally distinct configurations (Levy, 2005). The commutation here between phenomenon and meaning shows that every change in urban form corresponds to a change in meaning, and vice versa. However, the description of this phenomenon is based on varied and variable terminology, and several terms used in urban studies were changed at the hands of the authors. Such difficulty in pinpointing an accurate definition is particularly evident in the varying terminology used to describe urban phenomena. The term “Urban Mutation” appears, namely in the works of Neil Brenner (Neil, 2019), Bernard Calas (Calas, 2010), and Marcel Roncayolo (M. Roncayolo, 2001). Peter Bosselmann, (Bosselman, 2012) and Mark R. Montgomery (Montgomery, 2008) employed the term “Transformation”. While “Urban Changes” was used by Arefian (Arefian & Moeini, 2016) and Hilke Marit Berger (Berge & Ziemer, 2017), John Logan used the term “Transition” in John Friedmann’s book review (Logan, 2007), in addition to George Martine (Martine & McGranahan, 2010). Moreover,

“Gentrification” was employed by Neil Smith (Smith, 2002). This variety leads to a lack of consensus on terminology, epistemological weakness, and a lack of scientific rigor (Merlin & Choay 1988). Because of this diversity, understanding urban mutations and their challenges is crucial for both the operational and theoretical sides of urban planning and management. Thus, it is highly related to the evolution of scientific research in urban studies. In this context, and the face of this diversity, scientific research requires the establishment of a precise definition of concepts because it underlies the quality, credibility, and relevance of research work. It guarantees scientific rigor and integrity since it also avoids subjective interpretations. Hence, the expanding knowledge in science, technology, and humanities accentuates a reflection on the ins and outs of a field, its current situation, and its developmental prospects. Urban studies, with their extensive scientific contributions, are also part of this epistemological lineage and take root in established theories that follow this complexity. So, the evolving issues and concepts require an objective and contextual definition. The analysis of the relevant literature enables a systematic understanding and reveals insights into its diversity. To achieve a quantification of the literature, bibliometrics serves as a crucial tool since it permits the conduct of a quantitative analysis in temporal order according to changes in measurement objects such as keywords, article counts, and authors (Tao et al., 2022). It allows substantial theoretical and methodological contributions to the progressive visualization of knowledge fields. Hence, the effectiveness of scientific publications is usually studied through bibliometric research. Pritchard defined the term Bibliometry as “the application of mathematical and statistical methods to books and other means of communication” (Al, Taşkın, & Düzyol, 2012). This bibliometry enables the evaluation and examination of scientific production by studying the evolution and relationships between documents to build a systematic scientific framework (Sgambati & Gargiulo, 2022), which is conducted using several software programs. CiteSpace (version 6.2.R5 Advanced), an emerging software in the field of bibliometric data visualization, sorts, refines, and integrates citations in various articles, allowing the obtaining of essential information to be revised (Chen, 2016). This software facilitates the analysis of

emerging trends in a field of knowledge. It also offers several options for understanding and interpreting networks and historical models related to the growth of a field and its main citations through automatic labeling of the different groups (clusters) using the terms of the cited articles, the geospatial collaboration network, and international collaboration (Moral-Muñoz et al., 2020). The literature review of this study revolves around two major axes. While the first focuses on the significance of conceptualization in scientific research, highlighting the evolution of studies of theories in urban studies, the second reviews the articles combining bibliometry and urban studies, specifically those related to urban mutations. First, and in light of the importance of conceptualization in scientific research, numerous authors have significantly contributed to the reflection on the definition of concepts in scientific research, delving into the philosophical, epistemological, and historical dimensions of this subject. Thomas S. Kuhn discusses in his book (Kuhn, 1996), "The Structure of Scientific Revolutions", the evolution of scientific paradigms, which may include changes in the way concepts are defined (Desbois, 2013), and sometimes forces researchers who deal with the same subject into a whole reconstruction (Malherbe, 1974). Thomas Kuhn also provides the philosophical foundation for CiteSpace, the software that will be used to visualize the bibliometry of this research (Chen, 2017). Moreover, Ludwik Fleck (Fleck & Trenn, 1981) explores how scientific concepts develop and evolve in the social and historical context (Marecek, 2019; Martins, 2016; Young, 2018). Meanwhile, Ian Hacking treats the dynamics of the construction of scientific concepts as an understanding of how concepts, categories, and abstract entities are constructed (Hacking, 1999); (Jünger, 2023). Other influential works by Carl Hempel (Hempel, 1962), Nelson Goodman (Goodman, 1965), Willard Van Orman Quine (Quine, 1970), Hilary Putnam (Putnam, 1960), and Paul Thagard (Thagard, 1992) have shaped how researchers conceive, use, and define concepts in their respective fields of research. These works affirm the high significance of concept determination as a crucial element in the research structure. On the other side, theorization in urban studies has also followed the social, economic, political, and environmental transformations of cities by referring to the development of theoretical frameworks and

concepts to understand and analyze these urban phenomena. Among the classics addressing this topic, Jane Jacobs, author of "The Death and Life of Great American Cities" (1961), emphasizes, in her examination of urban dynamics, the significance of neighborhood vitality, social diversity, and planning focused on the residents' needs (Jacobs, 2016). Henri Lefebvre focused his work, "The Production of Space" (1974), on space production, which influenced urban theory and cultural geography (Lefebvre, 1992). Lewis Mumford explored the history of urban planning, technology, and culture. His work, "The City in History" (1961), focused on understanding how cities have evolved (Mumford, 1961). David Harvey discussed urban geography, globalization, and spatial justice. His work, "The Condition of Postmodernity" (1989), deals with contemporary urban theory (Lyotard, 1984). Michel Foucault addressed the question of power and surveillance in urban spaces, thus influencing urban theory, particularly through his writings on discipline and punishment (Foucault, 2013). Sharon Zukin studied gentrification and urban economy, which are explored in her book, "Naked City: The Death and Life of Authentic Urban Places" (Zukin, 2009). Saskia Sassen's publication, "The Global City: New York, London, and Tokyo" (1991), deals with urban globalization and the role of cities in the global economy (Sassen, 2013). Furthermore, other concepts were elaborated in other registers, namely the creative class by Richard Florida (Florida, 2019), the impact of information technologies on society and cities by Manuel Castells (Castells, 2010), and spatial justice by Edward Soja (Soja, 2013). It is noticed that the variety of concepts in these works evolves and spaces according to various approaches and lectures. This complexity makes reducing an urban phenomenon to a simple contextual definition difficult. The city is on the move, and so are its paradigms. Second, and due to this fragmentation and confusion of the research conclusions, bibliometry could be used as a method of quantitative literature analysis. It is more complete and objective than the sole analysis of the literature (Sheng et al., 2022). The consultation of the Scopus database, one of the largest curative databases covering scientific journals (Mongeon & Paul-Hus, 2016), yielded only 32 articles from 2016 to 2023. Few works have combined bibliometric research and urban studies, particularly regarding the concept of urban mutations.

It is attributed to penalization due to their field of research, the Humanities and Social Sciences (HSS), which differs from that of the material and life sciences on several levels (Maddi, 2018). Noteworthy employments of this analysis method include the analysis of the state of knowledge on the assessment of urban resilience, highlighting the emerging trends during different periods (Sharifi, 2020). Another study on Lake Taihu carried out a quantitative and qualitative comparative analysis of the development of current hotspots and future directions of research using a bibliometric analysis based on Science Citation Index (SCI) data (Zhang, Yao, & Qin, 2016). According to Cheng, the use of bibliometric software helps overcome the lack of quantitative analysis and evaluation of research results concerning land use change and food security. It allows the possibility of drawing the cooperative network and the co-occurrence map of keywords to analyze the progress and limitations of the research (Cheng *et al.*, 2021). The performance and development of research on the sustainable city between 1992 and 2016 have been reviewed using a bibliometric analysis based on the Science Citation Index Expanded (SCI-EXPANDED) and the Social Sciences Citation Index (SSCI) on Web of Science (Wang, Ho, & Fu, 2019). Another study on urbanization and climate change involved a systematic bibliometric review focused on optimization and resilience in the context of rainwater management practices (A. Islam, Hassini, & El-Dakhakhni, 2021). In the same register, the concept of “urban resilience”, a broader examination of the multidimensional concept, is carried out based on a bibliometric analysis of publications focused on cities (Nunes, Tomé, & Pinheiro, 2019). Further bibliometric analysis involves the exploration and mapping of literature in the field of peri-urban areas (Tiwari & Vajpeyi, 2023). Additionally, the identification of research perspectives and clusters in urban tourism (city tourism) in the narrow sense and tourist cities (cities and tourism) in the broad sense, aims to examine the complex relationship using scientific cartography. Hence, it deduces that the existing qualitative evaluations in this field can be verified and visualized experimentally (Hocevar & Bartol, 2021). In another register, the analysis of scientific production, dealing with the Life Cycle Analysis (LCA) of groundwater using bibliometric methods, contributes to the evolution of knowledge about this resource in terms

of use (environmental, economic, and social) (Herrera-Franco, Carrión-Mero, Montalván-Burbano, Mora-Frank, & Berrezueta, 2022). It is noteworthy that these references have highlighted the importance of the bibliometric approach in various areas of urban research. However, no studies have combined this approach with the concept of urban mutations. Therefore, the primary objective of this research is the evaluation of scientific publications to determine the prevalence and significance of terms used in the various articles related to urban mutations as well as to locate their conceptual and theoretical anchoring (Bailly, 1985), which is a basic foundation for any scientific research. This latter needs a set of theoretical and practical tools used to quantify experimental data (Moral-Muñoz, Herrera-Viedma, Santisteban-Espejo, & Cobo, 2020). Thereby, this study brings an original contribution to the literature of urban research, presenting a valuable conceptual framework to combine bibliometry and urban mutation concepts. This is rendered feasible using a deeply enormous web of research, with a total of 1768 articles filtered from an initial set of 5595 articles and documents through a very rational elimination process. Hence, this research aims to design a profile of studies on the concept of urban mutations and their different semantic formulations over a period from 1981 to 2023. In urban planning, “urban mutations”, “urban changes” and “urban transformations” are used interchangeably as three key concepts of this research. To achieve these objectives, a research survey was conducted in Algeria in 2023.

MATERIALS AND METHODS

This study conducts a bibliometric review. It is an analysis constructed by searching for research documents on a particular theme and discovering the results by analyzing these studies according to different characteristics (Marti-Parreño, Seguí-Mas, & Seguí-Mas, 2016). Initially, this study followed the PRISMA framework (Preferred Reporting Items Systematic Review and Meta-Analysis) (Page *et al.*, 2021), and the database used was Scopus. As demonstrated in the figure below (Fig. 1), the search started with the “identification” phase, in which a search by titles, abstracts, and keywords was launched with the three main keywords: “Urban Mutations”, “Urban Changes”, and “Urban Transformation” to identify the

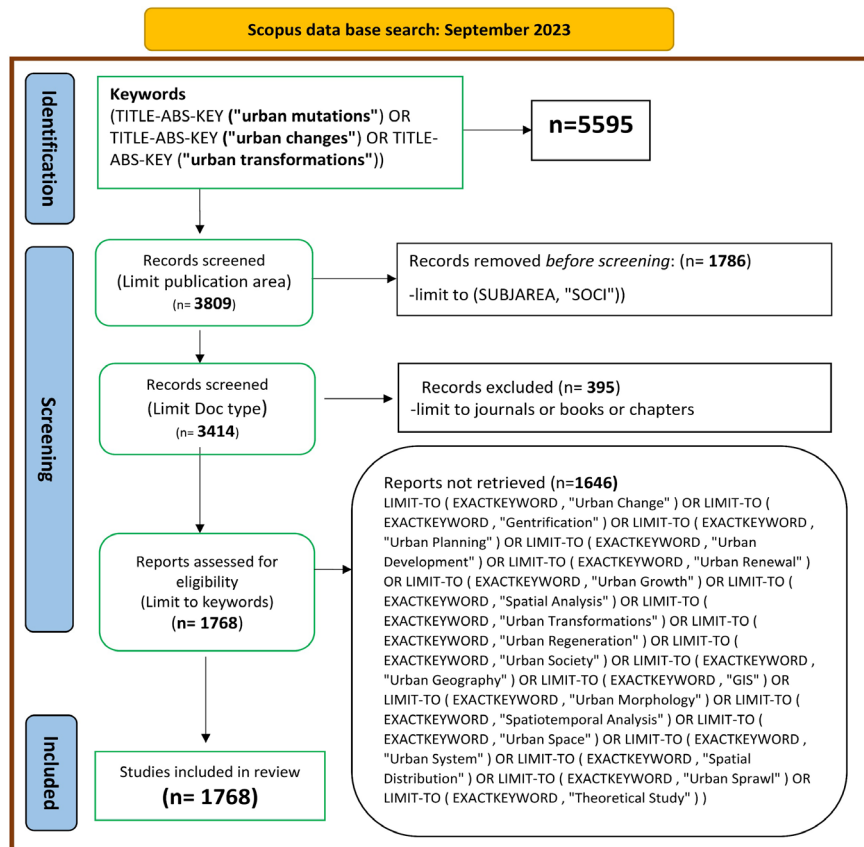


Fig. 1: PRISMA framework

conceptual possibilities of the terms. A total of 5595 documents were initially identified, spanning from 1981 to 2023. Next, the “screening” phase consisted of three steps of inclusion and exclusion criteria. The first step set “Limit publication area”, referred to as “SUBJAREA” (subject area), to “SOC” (social science). This excluded 1786 documents from the search for a new total of 3809. The second step included “Limit Doc Type” to “journals”, “books” or “chapters”, decreasing the screened records count to 395, leaving 3414 documents. In the third and last step, “Limit to keywords” was applied, including LIMIT-TO EXACTKEYWORD “Urban change”, “Gentrification”, “Urban Planning”, “Urban Development”, “Urban Renewal”, “Urban Growth”, “Spatial Analysis”, “Urban Transformations”, “Urban Regeneration”, “Urban Society”, “Urban Geography”, “GIS” (Geographic Information System), “Urban Morphology”, “Spatiotemporal Analysis”, “Urban Space”, “Urban

System”, “Spatial Distribution”, “Urban Sprawl”, OR “Theoretical Study”. This excluded 1646 from the total research documents. Hence, only 1768 documents were deemed eligible for analysis in the “Included” phase, as outlined in the PRISMA framework.

The entire process of progressive visualization is streamlined and implemented in the computer system, CiteSpace (Chen, 2004), which facilitates the analysis of emerging trends in a field of knowledge (Moral-Muñoz et al., 2020). In this study, CiteSpace (version 6.2.R5 advanced) was used for visualization analysis. In the analysis of co-occurrence or cooperation networks, labeling is based on the g-index. The time slot was set at 1 year, and the temporal division was made from 1981 to 2023. Pruning methods such as pathfinder, pruning sliced networks, and pruning the merged network have been used to simplify the network atlas. The included literature has been analyzed by authors, institutions, and countries. The

analysis of the co-occurrences, clusters, chronology, and detection of the burst terms was carried out with the keywords as nodes. The centrality metric (Freeman, 1977) is used by CiteSpace to highlight the potential pivot points of the paradigm shift over time as well as the detection of gusts (Kleinberg, 2002) which is adapted to identify emerging concepts in the research front. (Chen, 2006). The measurement of productivity quality is based on the g-index and not on the h-index. Three statistical methods, including the logarithm of the likelihood ratio (Log-Likelihood-Ratio LLR), Latent Semantic Indexing (LSI), and Mutual Information Tests (MITs), are applied in this process (Chen & Song, 2019). To achieve this objective, the focus was on three main points:

- 1) *Citation analysis, Analysis of the networks of co-authors, collaboration by country, and collaboration by institution,*
- 2) *Analysis of co-citations, the network of co-citation of documents, co-citation of authors, co-citation of journals,*
- 3) *Analysis of co-occurrences: Burst detection of keywords.*

To elaborate on this work, the following approaches are used:

- Data collection of articles dealing with the concept of urban mutations in the Scopus database.
- Perform filtering by inclusion and exclusion criteria according to a PRISMA diagram (Fig. 1).
- Export the Comma-Separated Value (CSV) format file to CiteSpace and convert the Scopus CSV file to Txt-WOS (Web of Science).
- Analysis using the software and visualization from an SVM-Structural Variation Mode- (Chen, 2012).

The CiteSpace workflow is briefly described in the following phases:

- i) *Detection of the domain of knowledge,*
- ii) *Data collection,*
- iii) *Extraction of search terms,*
- iv) *Temporal division,*
- v) *Selection of thresholds,*
- vi) *Pruning and fusion,*
- vii) *Visual inspection, and*
- viii) *Verification of crucial points (Moral-Muñoz et al., 2020).*

The modularity of a network provides insight into the internal structure of the network. The highly modularized structure signifies a network that essentially consists of weakly coupled components

(subnetworks) and a modularity approaching its highest end of 1. The silhouette score of a cluster measures its homogeneity. A cluster with a high silhouette score is considered more significant than a group with a low silhouette score. The centrality of the intermediary is defined for each node of a network. It measures the likelihood that an arbitrary shortest path in the network passes through the node. A node with a high centrality of intermediation is likely to be located in the middle of two large communities, or subnets, hence the name intermediary. In CiteSpace, a node with a high centrality between the two is represented by a purple ring.

RESULTS AND DISCUSSIONS

Citations analysis

Co-authors network analysis

The configuration adopted is: Timespan:1981-2023(Slice length=1), selection criteria: g-index (Scale factor k=25), Link retaining factor LRF=-1, Maximum link per node L/N=-1, Look back years LBY=-1, and Select top n items with citations or frequencies greater than or equal to e, e=2.0. The network output shows: Nodes N=728, Links E=2329, Density=0.0009, Modularity Q=0.983, Weighted Mean S=1, and Harmonic Mean (Q, S)=0.9916. Each node represents an author; the size of the node represents the number of times the author is cited, and the line width indicates the number of collaborative articles (Fig. 2). The highest-ranked author in terms of citation count is Salvati Luca (2018) in Cluster 1, with 10 citations, followed by Agergaard Jytte (2017) in Cluster 12. Nofre Jordi (2019) in Cluster 67, Lin George CS (2002) in Cluster 195, and Casellas Antònia (2005) in Cluster 437 have a similar citation count of 4. Subsequently, Raven, Rob (2021) in Cluster 4, Jenkins, Paul (2015) in Cluster 7, Camagni Roberto (2014) in Cluster 21, and López-gay Antonio (2021) in Cluster 14, each have 3 citations. In the 10th position comes Batty Michael (2003) in cluster 0, with 2 citations (Table 1).

Analysis of the collaboration network by country

The configuration adopted is: Timespan:1981-2023(Slice length=1), selection criteria: g-index(k=25), LRF=-1, L/N=-1, LBY=-1, e=2.0. The network output shows N=859, E=1437, and Density=0.0039. Modularity Q=0.667, Weighted Mean S=0.933, and Harmonic mean (Q, S)=0.7743. In the citation degree ranked by its count, the United Kingdom holds the

Table 1: Most cited authors (1981-2023)

Citation Count	Author	CI.ID	Institution	Country
10	Salvati, Luca, 2018	1	Sapienza Università di Roma,	Rome, Italy
4	Agergaard, Jytte, 2017	12	Københavns Universitet	Copenhagen, Denmark
4	Nofre, Jordi, 2019	67	Universidade Nova de Lisboa	Lisbon, Portugal
4	Lin, George CS, 2002	195	The University of Hong Kong	Hong Kong, Hong Kong
4	Casellas, Antònia, 2005	437	Universitat Autònoma de Barcelona	Cerdanyola del Valles, Spain
3	Raven, Rob, 2021	4	Monash University	Melbourne, Australia
3	Jenkins, Paul, 2015	7	University of the Witwatersrand,	Johannesburg, South Africa
3	Camagni, Roberto, 2014	21	Politecnico di Milano	Milan, Italy
3	López-gay, Antonio, 2021	14	Universitat Autònoma de Barcelona	Cerdanyola del Valles, Spain
2	Batty, Michael, 2003	0	University College London	London, United Kingdom

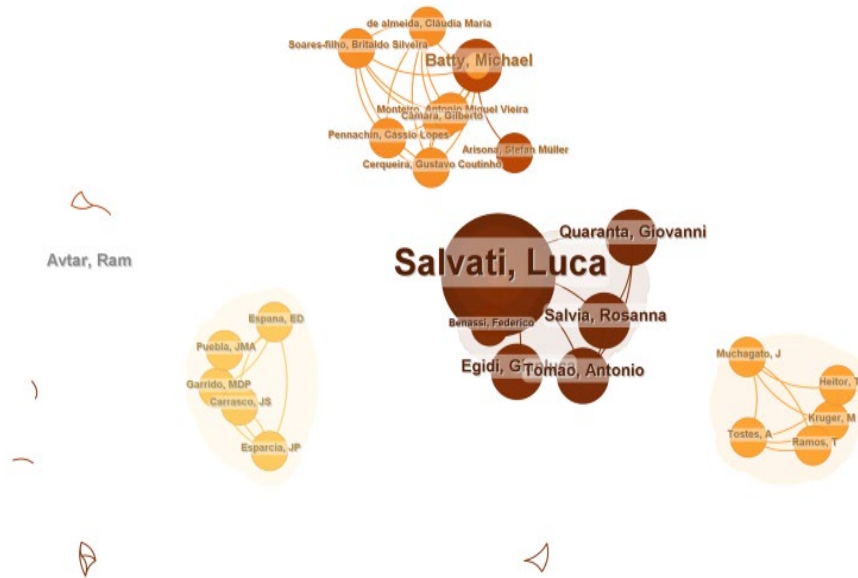


Fig. 2: Visualization of the authors' collaboration network

top position with 287 citations in Cluster 1, labeled as “Urban Transformation” by LSI. It is followed by the United States in Group 3, with 239 citations. Italy is in Group 0, with 127 citations, followed by Germany in Group 2, with some 110 citations. China is in Group 4, with 96 citations, and Spain is in Group 0, with around 95 citations. The Netherlands is in Group 5, with 93 citations. Turkey, in group 2, has some 88 citations. Australia comes in the 9th position in Group 4 with 81 citations, and France follows in the 10th spot in Group 1 with some 78 citations (Table 2).

The United Kingdom retains its top position in terms of centrality, registering 0.35 in the largest Cluster (1), labeled as “Urban Transformation” by LSI (Table 3). Germany comes second in Group 2, with a centrality of 0.20. The Netherlands holds the

third position in Group 5, with a centrality of 0.18. The United States moves to 4th place in Group 3, with a centrality of 0.17, followed by Italy (0.13), France (0.12), Japan (0.09), and Spain (0.08). Finally, both China and Australia hold the last positions with a centrality of 0.06. In CiteSpace, a node with a high centrality between two others is depicted by a purple ring (Fig. 3).

Analysis of the institutions' collaboration network

The configuration adopted is: Timespan:1981-2023 (Slice length=1), selection criteria: g-index(k=25), LRF=-1, L/N=5, LBY=-1, e=1.0. The network output shows: N=1314, E=4984, Density=0.0059, Modularity Q=0.707, Weighted Mean S=0.8413, and Harmonic mean (Q,S)=0.7683. When analyzing the institutions

of the co-authors in the Scopus documents, “Institution” is selected as the type of node. The largest group (0) comprises 158 members and has a silhouette value of 0.672. It is labeled as “Peri-Urban Transformation” by LLR, “Urban Transformation” by LSI, and “Comparative Statistical Analysis (1.1)” by MI. The most cited article within this group is Nahiduzzaman, KM’s “Urban Transformation towards a Smart City: An E-Commerce-Induced Path-Dependent Analysis. Journal of Urban Planning and Development” (Nahiduzzaman *et al.*, 2021). The most frequently cited terms within the group are “Urban Areas” (73 citations), “Urban Regeneration” (57 citations), and “Metropolitan Areas” (29 citations). Geographical visualization allows for the identification of the authors’ geographical locations through a geospatial map in KML. The Google Earth interface is used to obtain this representation, enabling the exploration of the authors’ locations, links to their collaborators, and direct access to the original articles within Google Earth (Moral-Muñoz

et al., 2020). The red dot on the map represents the specific geographical distribution of the research on the subject (Fig. 4).

Co-citation analysis

Co-citations can be considered as a special case of co-occurrences, encompassing co-occurring words, or co-words, and other types of entities such as co-authors or author co-citations. Essentially, co-citations refer to the fact that two references are cited together by a third article (Chen, 2013).

Analysis of the document co-citation network

The configuration adopted is: Timespan:1981-2023(Slice length=1), selection criteria: g-index(k=25), LRF=-1, L/N=-1, LBY=-1, e=0.7. The network output shows: N=1897, E=28008, Density=0.0156, Modularity Q=0.9125, Weighted Mean S=0.9622, and Harmonic Mean (Q,S)=0.9367. The entropy graph over time illustrates the evolution of entropy according to the appearance of new terms or keywords. A higher

Table 2: Ranking of citation degree by citation count and centrality

Citation Count	Node	Year	Cluster-ID	Centrality	Node	Year	Cluster-ID
287	United Kingdom	1985	1	0.35	United Kingdom	1985	1
239	United States	1981	3	0.20	Germany	1999	2
127	Italy	1988	0	0.18	Netherlands	2004	5
110	Germany	1999	2	0.17	United States	1981	3
96	China	2003	4	0.13	Italy	1988	0
95	Spain	1998	0	0.12	France	1997	1
93	Netherlands	2004	5	0.09	Japan	1995	4
88	Turkey	2001	2	0.08	Spain	1998	0
81	Australia	1990	4	0.06	China	1990	4
78	France	1997	1	0.06	Australia	2001	4

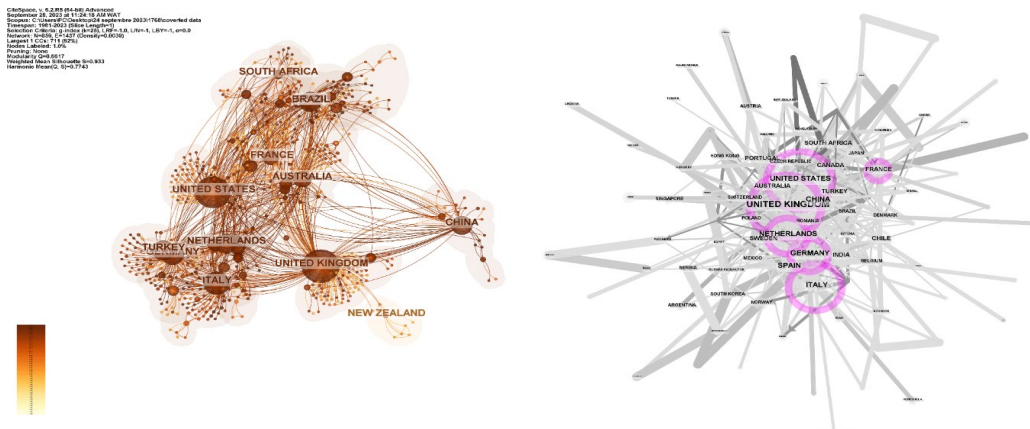


Fig. 3: Visualization of the countries' network

Table 3: List of the 7 biggest clusters

Cluster. ID	Size	Silhouette	Label (LSI)	Label (LLR)	Label (MIT)	Year
0	20	0.705	Urban Transformation	Socio-Spatial Analysis	Public Sector	2008
1	18	0.593	Global South	South Africa	Public Sector	2005
2	18	0.602	Urban Transformation	Urban Public Open Space	Public Sector	2008
3	13	0.66	Urban Change	Urban China	Public Sector	2005
4	11	0.693	Case Study	Case Study	Tourism-Led Peri-Urban Transformation	2007
5	9	0.866	Post-Socialist Cities	Post-Socialist Cities	Public Sector	2007
6	4	0.924	Comprehensive Methodology	Smart City Intervention	Urban Transformation	2017

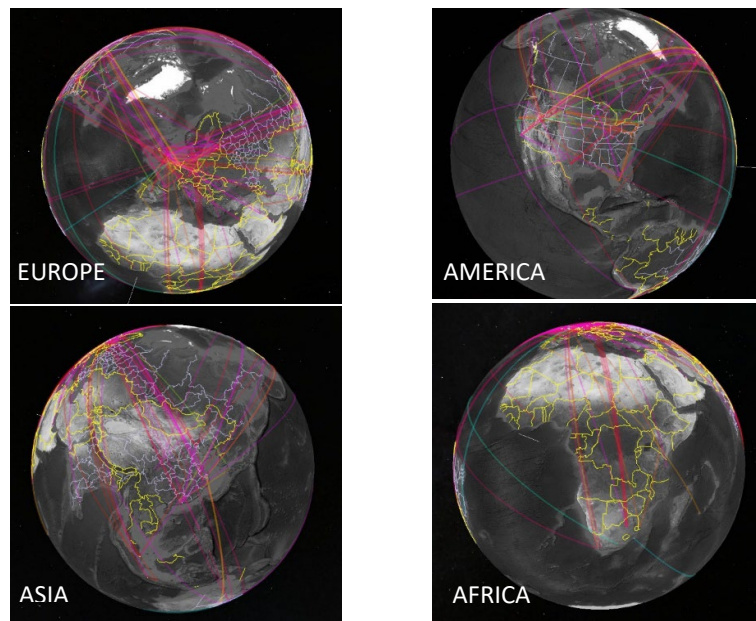


Fig. 4: Geographic data map, interaction CiteSpace software, and Google map

entropy denotes the introduction of a considerable number of new concepts underlying a research area (Chen, 2008). The result of the analysis generated by CiteSpace shows a network consisting of 17 Clusters; the first 10 are shown in (Table 4, Fig. 5). The largest cluster (0) comprises 501 members and has a silhouette value of 0.917. It is labeled as “Embracing Complexity Ambiguity” by LLR and “Urban Change” by LSI. The most cited article of the group is Nickayin, SS “Qualifying Peripheries or Repolarizing the Center: A Comparison of Gentrification Processes in Europe” (Nickayin et al., 2020). The most frequently cited members of this cluster include 51 quotes from Smith N., 1996, “The New Urban Frontier: Gentrification and the Revanchist City” (Smith, 1996), 46 quotes also for Smith N, “New Globalism New

Urbanism: Gentrification as Global Urban Strategy” (Smith, 2002), and 45 quotes for Lefebvre et al., “The Production of Space” (Lefebvre, Nicholson-Smith, & Harvey, 1991). The silhouette score is between 0.917 and 1, indicating a very reliable grouping result. In terms of citation count, Smith, “The New Urban Frontier: Gentrification and the Revanchist City”, holds the first position with a total of 97 (51+46) citations, followed by Lefebvre with 45 citations, Lees L (68 citations), Jacobs J (38 citations), and Harvey D. in 9th position with 27 citations (Table 5 and Fig. 6). However, this classification shifts when considering centrality. Harvey D., “From Managerialism to Entrepreneurship: The Transformation in Urban Governance in Late Capitalism” takes the first place, becoming the most linked reference to the rest of the

citation networks, followed by Massey and Sassen. Hence, Smith N falls back to 7th place (Table 6).

Analysis of the authors' co-citation network

The configuration adopted is: Timespan:1981-2023(Slice length=1), selection criteria: g-index (k=25), LRF=-1, L/N=-1, LBY=-1, e=1.0. The network output shows: N=1137, E=5878, Density= 0.0091), Modularity Q=0.6881, Weighted Mean S=0.8005, and Harmonic mean (Q,S)=0.7410. The largest group (0) encompasses 137 members and has a silhouette value of 0.74. It is labeled as “Transnational Gentrification” by LLR, “urban change” by LSI, and “urban vitality” by MIT.

The main article in this group is by Nickayin, SS “Qualifying Peripheries or Repolarizing the Center”: A Comparison of Gentrification Processes in Europe” (Nickayin et al., 2020). The most cited members of this group include 347 citations for Harvey D, 199 for Smith N, and 138 for Lees L. The second cluster consists of 129 members with a silhouette value of 0.728. It is labeled as “Soft Urban Densification” by LLR, “Urban Transformation” by LSI, and “Urban Vitality” by MIT. The most cited article from the cluster is Nielsen’s “Conceptualizing the Built Environment to Inform Sustainable Urban Transitions” (Nielsen & Farrelly, 2019). The most

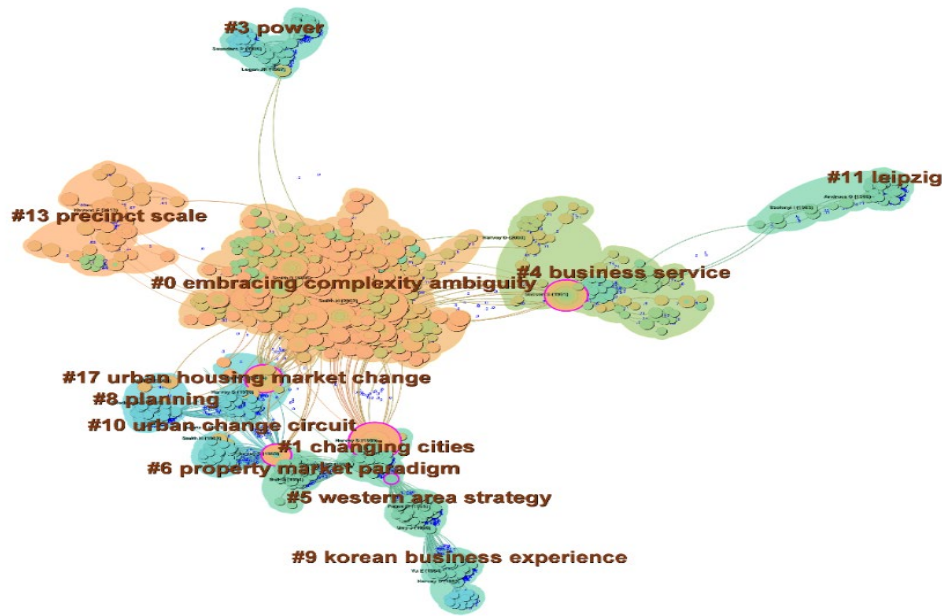


Fig. 5: Co-citation of authors' documents by clusters

Table 4: List of the 10 biggest clusters

Cluster-ID	Size	Silhouette	Label (LSI)	Label (LLR)	Year
0	501	0.917	Urban Change	Embracing Complexity Ambiguity	2003
1	85	0.991	Changing Cities	Changing Cities	1991
2	81	1	Towards an Urban Evolutionary Theory	Orie	1980
3	80	1	Power	Power	1983
4	78	0.977	Business Service	Business Service	1994
5	76	0.986	Multiscaled Interpretations of Urban Change	Western Area Strategy	1991
6	74	0.984	Property Market Paradigm	Property Market Paradigm	1985
7	71	1	Italian Town Planning and the Idea of the City in the Early Twentieth Century	City	1929
8	64	0.989	Planning	Planning	1987
9	62	0.998	Responses to Spatial Rigidity in Urban Transformation: Korean Business Experience in Los Angeles	Korean Business Experience	1984

Table 5: Top 10 references based on citation count

Cluster-ID	Count	Centrality	Year	Cited References
1	51	0.09	1996	Smith N, The New Urban Frontier: Gentrification and The Revanchist City,
2	46	0.04	2002	Smith N, New Globalism,
3	45	0.06	1991	Lefebvre H, The Production of Space,
4	39	0.06	2008	Lees L, Gentrification,
5	38	0.06	1961	Jacobs J, The Death and Life of Great American Cities,
6	29	0.00	2016	Lees L, Planetary Gentrification,
7	27	0.19	1989	Harvey D, From Managerialism to Entrepreneurialism: The Transformation in Urban Governance in Late Capitalism,
8	24	0.06	2005	Massey D, For Space,
9	24	0.01	1996	Ley D, The New Middle Class and The Remaking of The Central City,
10	22	0.01	2006	Robinson J, Ordinary Cities: Between Modernity and Development

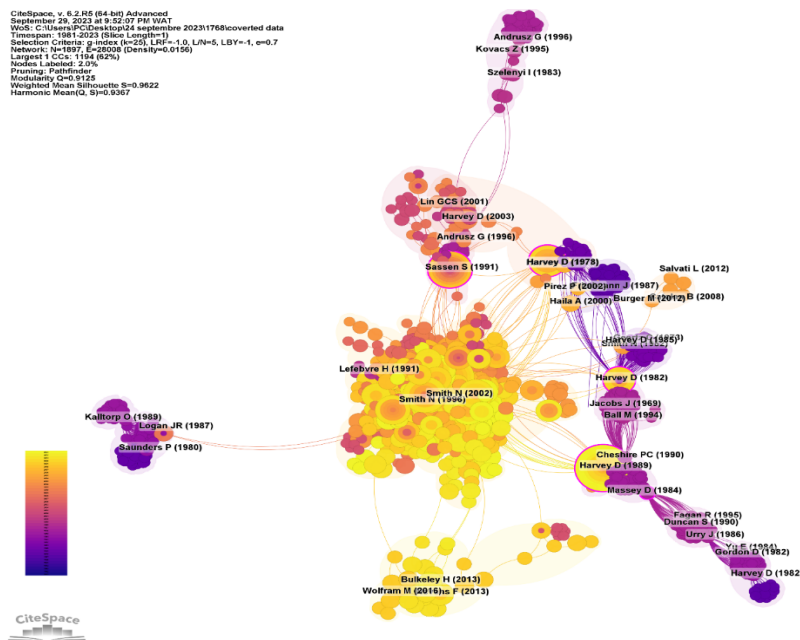


Fig. 6: Co-citation of authors' documents

cited members of the group are 162 for Lefebvre H, 104 for Robinson J, and 85 for Roy A. The third largest cluster (2) has 119 members and a silhouette value of 0.809. It is labeled as "South Shoreditch" by LLR, "Urban Transformation" by LSI, and "Urban Vitality" by MIT. The main article cited in this cluster is Nielsen's "Conceptualizing the Built Environment to Inform Sustainable Urban Transitions" (Nielsen & Farrelly, 2019). The most cited members of this cluster are 132 for Sassen S, 102 for Florida R., and 72 for Jacobs J. (Fig. 7). The highest-ranked article by number of citations is Harvey D. (1988) in cluster O, with 347 citations, followed by Smith N. (1988) with

199 citations, Brenner N. (2004) with 147, Lefebvre H. (2005) with 162, Lees L. (2010) with 138, Sassen S. (1998) with 132, Zukin S. (2003) with 132, Castells M. (1988) with 116, Peck J. (2008) with 107, and finally Robinson J. (2008) with 104 citations. The article best classified by the degree of centrality is Amin A. (2020) in cluster 7, with a centrality of 0.21. The second is Castells M. (1988) in cluster 5, with a centrality of 0.19 followed by Hall P. (1982) with 0.13, Sassen S. (1998) with 0.10, Batty M. (1994) with 0.10, Alonso W. (1982) with 0.09, Harvey D. (1988), and finally Friedmann J. (1982), Wu F. (2000) and Davison G. (1978) with a centrality of 0.08 (Table 7).

Table 6: Top 10 references based on centrality

Cluster-ID	Count	Centrality	Year	Cited References
1	27	0.19	1989	Harvey D, From Managerialism to Entrepreneurialism: The Transformation in Urban Governance in Late Capitalism
2	9	0.17	1982	Harvey David, The Limits to Capital
3	2	0.16	1984	Massey D, Spatial Divisions of Labour: Social Structures and The Geography of Production
4	13	0.13	1973	Harvey D, Social Justice, and The City
5	18	0.12	1991	Sassen S, The Global City: New York
6	3	0.10	1987	Logan JR, Urban Fortunes: The Political Economy of Place
7	51	0.09	1996	Smith N, The New Urban Frontier: Gentrification and The Revanchist City
8	2	0.08	1986	Urry J, Locality Research: The Case of Lancaster: Regional Studies
9	2	0.08	1990	Cheshire PC, Explaining the Recent Performance of The European Communities Major Urban Regions
10	4	0.08	1996	Andrusz G, Cities After Socialism: Urban and Regional Change and Conflict in Post-Socialist Societies

Analysis of the network of co-citations of the journals

The configuration adopted is: Timespan:1981-2023(Slice length=1), selection criteria: g-index (k=25), LRF=-1, L/N=-1, LBY=-1, e=15. Network: N=1258, E=11036, Density=0.014), Modularity Q=0.6831, Weighted Mean S=0.8005, and Harmonic mean (Q, S)=0.7410. The articles included in the analysis come from various journals whose main groups are presented in Figure 8. Among the top ten most cited journals, “Urban Studies” holds the highest frequency with 602 co-citations, followed by “International Journal of Urban and Regional Research” with 454 co-citations (Table 8). In terms of centrality (Table 9, Fig. 8), the main journals in this field include the “International Journal of Urban and Regional Research” (0.29), “Urban Studies” (0.22), “Environment and Planning” (0.20), and in descending order, “Administrative Science Quarterly”, “Cities”, “Annals of the Association of American Geographers”, “Urban Geography”, “Progress in Human Geography”, “Journal of the American Planning Association”, and “Journal of Planning Education and Research”. “Urban Studies” and “International Journal of Urban and Regional Research” consistently hold the first two positions, indicating their significant influence in connecting the different publications and journals, which is highly valuable for researchers dealing with urban mutations. It is noteworthy that these two journals remain prominent despite not having the highest impact factors or CiteScore compared to others like “Cities”, “Administrative Science Quarterly” and “Progress in Human Geography”. This can be attributed to the fact that urban mutations as a topic does not represent all the themes of the articles published by these journals, whose interest could be highlighted in

other topics. The impact factor and the CiteScore are taken from the websites of the concerned journal, and the clusters grouped by CiteSpace with the LSI algorithm are labeled in equal partitions between “Urban Change” and “Urban Transformation”.

Analysis of co-occurrences

The configuration adopted is: Timespan: 1981-2023 (Slice length=1), selection criteria: g-index (k=25), Link retaining factor LRF=-1, L/N=-1, Look back years LBY=-1, e=1.0. The Network output shows: Nodes N=1244, E=19653, Density= 0.0254, Modularity Q=0.521, Weighted Mean S=0.720, and Harmonic Mean (Q, S) =0.605. The modularity Q value is 0.551, which is greater than the critical value of 0.3, indicating a good clustering effect of the keyword network. Similarly, the T value of the average silhouette, at 0.720, exceeds the critical value of 0.5, indicating a reasonable cluster effect. The Log LSI algorithm is selected to obtain the map of the clusters of keywords in the Scopus documents. In the analysis of the keywords’ centrality, frequency represents the number of occurrences of a keyword, while centrality signifies its importance. A higher frequency reflects the popularity of the search direction. Burstiness, or bursting, measures the rate of change (Kleinberg, 2002) and (Chen, 2016).

Burst detections of keywords

Keywords are the refinement of the content, fully reflecting the author’s academic thoughts and perspectives. The concept of “burst” keywords refers to terms that experience high usage frequency over a shorter timeframe, indicating a notable focus by

researchers during a specific period. Analyzing the change in the frequency of emerging words allows for insights into the evolving boundaries and trends of this field of research. The table below (Table 10) provides a list of the first 19 keywords with the strongest bursts. The last column represents the timeframe of the study (1981-2023), and the red line indicates the duration of the keywords' appearance. In terms of burst strength, Eurasia holds the top position with a value of 40, followed by Urban Change with 35.13, spanning from 1987 to 1998. Europe ranks third with 22.07, followed by Asia (15.59), Western Europe (10.56), Far East (10.14), Sustainability (9.32),

World (8.69), North America (8.16), and Urban Policy (7.52), all registering burst strength exceeding 7. These burst keywords reflect the characteristics of a certain period. Observing the data reveals that terms with high burst strength predominantly emerged in the early 21st century, particularly around the year 2000, albeit with limited durations. On the other hand, the terms "Urban Economy", "Globalization", "Geographic Factors", "Geography", and "Article" persist over a longer period of 16 years. The most recent term, "Sustainability", maintained relevance from 2019 to 2023 (Table 10).

The analysis of the keywords based on citation

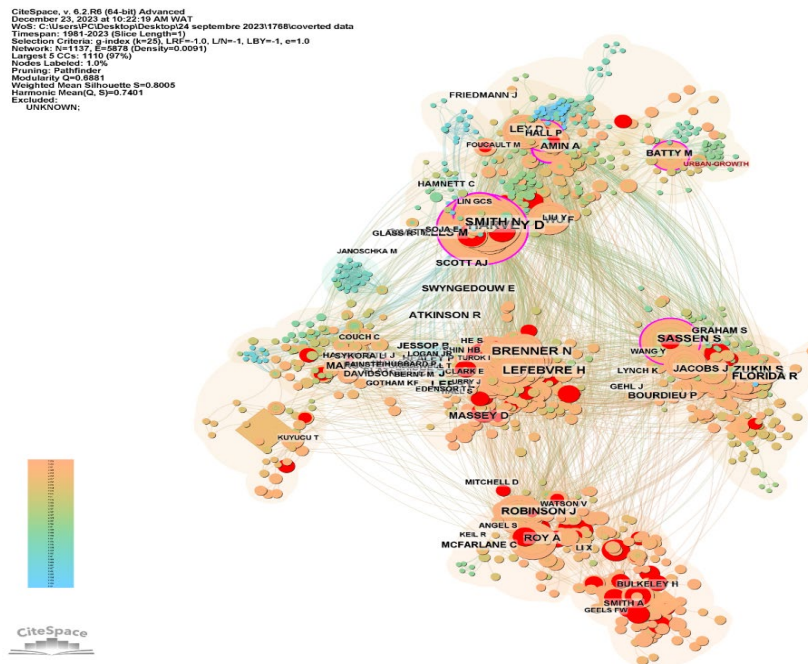


Fig. 7: Authors' co-citations network

Table 7: Classification by citations count and centrality

Classification by Citation Count			Classification by centrality		
References	Citation Count	Cluster-ID	References	Centrality	Cluster-ID
Harvey D, 1988	347	0	Amin A, 1996	0.21	7
Smith N, 1988	199	0	Castells M, 1988	0.19	5
Brenner N, 2004	174	7	Hall P, 1982	0.13	2
Lefebvre H, 2005	162	1	Sassen S, 1998	0.10	2
Lees L, 2010	138	0	Batty M, 1994	0.10	8
Sassen S, 1998	132	2	Alonso W, 1982	0.09	10
Zukin S, 2003	132	0	Harvey D, 1988	0.08	0
Castells M, 1988	116	5	Friedmann J, 1982	0.08	2
Peck J, 2008	107	0	Wu F, 2000	0.08	6
Robinson J, 2008	104	1	Davison G, 1978	0.08	0

frequency and centrality is presented in the table below (Table 11). Notably, the keywords “Urban Change” (0.41), “Urban Planning” (0.10), and

“Developing Country” (0.08) show higher centrality scores, although with considerable temporal gaps, starting from 1981, 1997, and 1985 respectively. The

Table 8: Top 10 most cited journals based on citation frequency

Count	References	Impact Factor	Cite Score Scopus	Year
602	Urban Studies	4.7	7.1	1996
454	International Journal of Urban and Regional Research	3.3	7.1	1988
408	Cities	6.7	10.4	1999
290	Environment and Planning A	4.2	7.2	1982
244	Urban Geography	3.8	7.2	1988
216	Progress in Human Geography	7.1	14.6	1991
210	City	-	3.0	2009
202	Antipode	4.24	5	1997
160	Sustainability	3.88	2.3	2017
147	European Planning Studies	2.8	7.0	1996

Table 9: Top 10 cited journals based on centrality

Centrality	References	Impact Factor	Cite Score Scopus	Year
0.29	International Journal of Urban and Regional Research	3.3	7.1	1988
0.22	Urban Studies	4.7	7.2	1996
0.20	Environment and Planning A	4.2	7.2	1982
0.09	Administrative Science Quarterly	10.4	21.1	1989
0.08	Cities	6.7	10.4	1999
0.08	Annals of the Association of American Geographers	3.9	7.4	1991
0.07	Urban Geography	3.8	7.2	1988
0.04	Progress in Human Geography	7.1	14.6	1991
0.04	Journal of the American Planning Association	5.6	9.4	1988
0.04	Journal of Planning Education and Research	2.2	10.7	1988

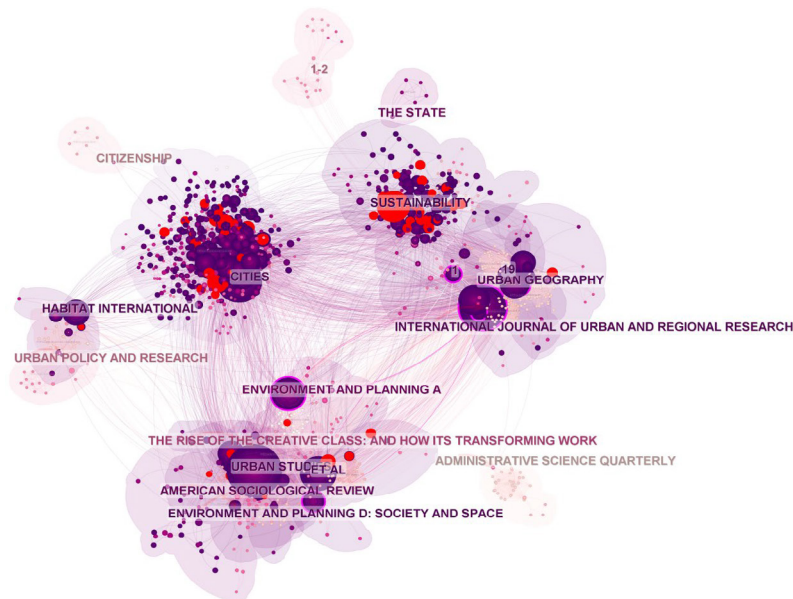


Fig. 8: Cited journals network based on centrality

most recent keywords, “Urban Design” (0.06), “Urban History” (0.05), and “Decision Making” (0.04), dating from the year 2000 show low centrality. In terms of the citation frequency, “Urban Development” ranks first with 550 citations, followed by “Urban Planning” with 489 and “Urban Transformation” with 384 citations. However, “Urban Change” falls back to the 5th position with 211 citations. (Fig. 9).

Theoretical and practical implications

In summary, this study evidences the importance of analyzing the role of conceptualization in urban studies. It contributes to the urban research literature by providing a practical conceptual framework combining bibliometry and urban mutation concept. It also constitutes an essential tool for researchers, students, and professionals who wish to familiarize themselves with a research topic, deepen their knowledge in a specific field, determine originality and innovation in the field, and adapt the focus of their research to the field or technologies favored by the high impact factor journals in which they wish to publish. Using Citespace in this study paved the way for an analysis that addresses the gap in the

literature by providing an overview of urban mutation output. Hence, scientometric analysis plays a crucial role in identifying potential relationships within the literature, monitoring the evolution of research knowledge on conceptualization, and guiding the use of research-specific terminology, thus ensuring rigor and integrity. Moreover, this study provides an overview of existing research, identifying the methodologies used, highlighting the main theories and concepts, and determining trends and challenges in the field. This analysis leads to reconsidering the urban mutations, causing an urge to think differently about the city (mutation of knowledge about the city), and to also make it differently (mutation of the shape of the city). Finally, this study also shows that concepts related to the evolution of cities go beyond the spatial and morphological approach into other a-spatial implications, especially regarding productivity and globalization notions (Eurasia, Europe, Western Europe, Far East, World, North America, etc.). These are indicators of the trend towards collaborative research, highlighting the international dimension without omitting the new economy based on knowledge and information that are gradually permeating

Table 10: Strength burst citation keywords

Keywords	Year	Strength	Sart	End	1981 - 2023
Eurasia	2004	40	2004	2009	
Urban Change	1981	35.13	1987	1998	
Europe	1989	22.07	2004	2009	
Asia	1985	15.59	2003	2009	
Western Europe	2004	10.65	2004	2009	
Far East	1998	10.14	2005	2009	
Sustainability	2014	9.32	2019	2023	
World	2004	8.69	2004	2005	
North America	2004	8.16	2004	2007	
Urban Policy	1988	7.52	2011	2014	
Developing Country	1985	7.4	1985	1998	
Political Economy	2002	7.01	2015	2019	
Southern Europe	2007	6.97	2007	2009	
Urban Economy	1997	6.87	1997	2013	
Globalization	2000	6.79	2000	2016	
Geographic Factors	1982	6.24	1982	1998	
Geography	1982	6.24	1982	1998	
Article	1982	6.09	1982	1999	
United Kingdom	1999	5.75	1999	2008	

the strategies and ways of design, production, and management of the cities themselves.

Suggestions for future research

As the concepts “urban change” and “urban

transformation” predominate in literature, it would be desirable to direct future research to other concepts that have emerged during the last ten years. This would involve a multidisciplinary approach that can guide decision-making, improve the allocation of resources,

Table 11: Summary of keywords by centrality and frequency

Classification by Centrality				Classification by Citation			
Keywords	Count	Centrality	Year	Keywords	Count	Centrality	Year
Urban Change	211	0.41	1981	Urban Development	550	0.07	1988
Urban Planning	489	0.10	1997	Urban Planning	489	0.10	1997
Developing Country	14	0.08	1985	Urban Transformation	384	0.05	1988
Urbanization	235	0.08	1982	Urbanization	235	0.08	1982
Spatial Analysis	90	0.07	1995	Urban Change	211	0.41	1981
Urban Development	550	0.07	1988	Urban Area	206	0.04	2004
Urban Population	61	0.07	1982	Urban Renewal	156	0.04	1987
Australia	16	0.06	1990	China	153	0.05	1998
Demography	29	0.06	1982	Urban Growth	144	0.03	2002
Economics	16	0.06	1985	Neighbourhood	135	0.02	2006
Urban Design	79	0.06	2000	Gentrification	124	0.02	1987
Urban Economy	97	0.06	1997	Urban Policy	119	0.05	1988
Article	20	0.05	1982	Urban Economy	97	0.06	1997
Canada	27	0.05	1993	Spatial Analysis	90	0.07	1995
China	153	0.05	1998	Sustainability	84	0.01	2014
Europe	64	0.05	1989	Urban Design	79	0.06	2000
Urban History	45	0.05	2000	Sustainable Development	77	0.02	2009
Urban Policy	119	0.05	1988	Urban Transformations	73	0.01	2012
Urban Transformation	384	0.05	1988	Governance Approach	73	0.02	1998
Decision Making	30	0.04	2000	Urban Regeneration	68	0.02	2009

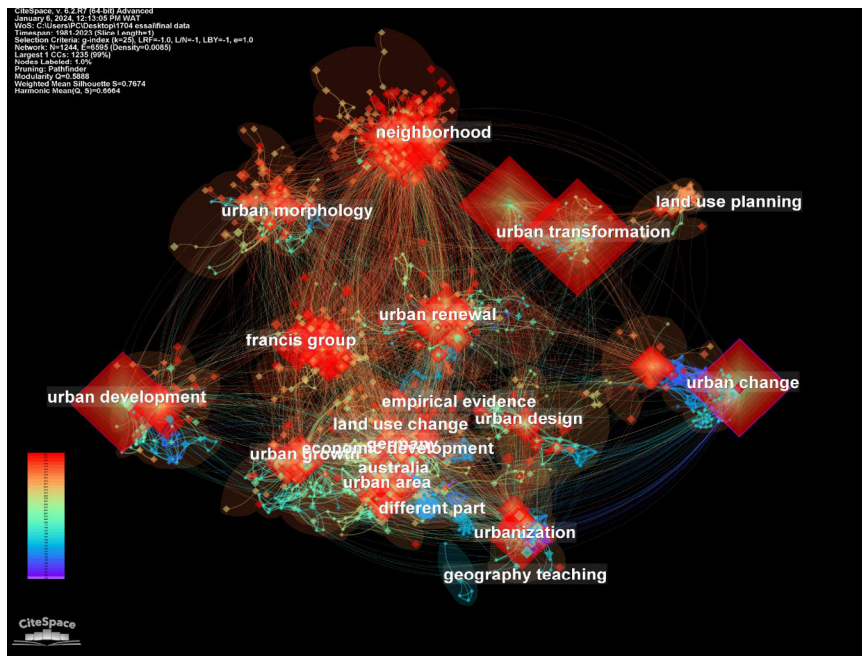


Fig. 9: Visualization of keywords centrality analysis

and predict trends (Urban Planning, Urban Policy, Urban Economy, Governance Approach, Decision Making). In addition, incorporating another database, such as the WOS, PubMed, and Dimension, would provide a better understanding of the concept by expanding the scope of the keywords which would enrich the research with a broader data field. Moreover, using a different label than the g-index could improve the search, such as selecting the top 50 levels or a higher percentage of the most cited or most frequent items within each yearly slot. Furthermore, this research's database heavily revolved around English literature, penalizing other sources from different countries. Thus, it would be a great contribution to extend the range of the study to non-English speaking countries, which are poorly represented in international databases. It is important to explore research in other linguistic contexts to see the results of other theoretical models similar to this type of research. At last, it is recommended to resort to another type of database called Altemetrics, or alternative metrics such as Mendley Interface, which measures, not only citations but also the social impact of publications through the analysis of the number of downloads, views, shares, etc.

Limitations

Nevertheless, it should be mentioned that this research still has certain limitations. First, this study had a certain type of restriction considering the access to the databases. The retrieved documents relied only on a single database, Scopus, which is not wide enough to cover all the international documents in the field of study despite its enormous nature. Second, the limited collected data was due to the use of only three terms, "Urban Mutation", "Urban Change" and "Urban Transformation". These latter were picked as seen fit to the study's main objectives. In addition, the interlingual nature of research imposes a certain degree of distinction in the use of particular terms, and thus it could lead to confusion in concept definition and semantic range. Third, technical challenges were encountered during the conversion of the CSV file from the Scopus database to a standard format. CiteSpace has addressed this by integrating conversion directly in version 5.7. Besides, the results of the bibliometric analysis are sensitive to the time factor since the database is updated dynamically. Finally, it should be noted that bibliometrics does not measure a

researcher's scientific output or impact, but simply gives a numerical evaluation of the citations of each researcher, and the use of traditional databases neglects the social impact of publication.

CONCLUSION

This study has enabled the identification of the research topics most related to the concept of urban mutations. It is based on a bibliometric review of 1768 documents taken from the Scopus database. The analysis of the co-citations and visualization of the reference network on the concept of urban mutations was conducted using the CiteSpace software. Moreover, this study elucidated the conceptual trends relating to the urban mutation phenomenon and tracked the process of the evolution of research in this field by detecting the guiding trends. The analysis of scientific output on urban mutations reveals that the highly ranked country by academic production is the United Kingdom, as the main contributor with the highest number of citations, followed by the United States of America, Italy, and Germany. It is noted that the largest number of articles developed in this field belonged to European or English-speaking countries. In terms of authors, Salvati Luca (2018) from Sapienza Università di Roma, Italy, holds the largest number of articles on this topic, followed by Jytte Agergaard (2017) from Københavns Universitet, Denmark, Jordi Nofre (2019) from Universidade Nova de Lisboa, Portugal, George Lin CS (2002) from The University of Hong Kong, China, and Antònia Casellas (2005) from Universitat Autònoma de Barcelona, Spain. The cluster analysis of the document co-citation network, generated by Citespace and based on their size, highlights Urban Change (2003), Changing Cities (1991), Towards an Urban Evolutionary Theory (1980), Power (1983), Business Service (1994), and Multiscaled Interpretations (1991) as the main research topics. "Urban Change" is the most recent topic in 2003. The most cited article of the group is Samaneh Nickayin's "Qualifying Peripheries or Repolarizing the Center: A Comparison of Gentrification Processes in Europe". Moreover, the most frequently cited member is Smith N., 1996, "The New Urban Frontier: Gentrification and the Revanchist City". As for the references' co-citation, it is worth mentioning the dominance of Smith N., Lefebvre H., Lees L., and Jane Jacobs. Concerning the authors' co-citation, Harvey D., Smith N., Brenner N., and Lefebvre H. hold the top positions in terms of the degree of citations. The most recent reference

belongs to Robinson J.'s, "Ordinary Cities: Between Modernity and Development" (2006). Concerning the author co-citation network, the classification by citation count ranks Neil Smith, "The New Urban Frontier: Gentrification and the Revanchist City", first. However, the classification by centrality ranks David Harvey, "From Managerialism to Entrepreneurship: The Transformation in Urban Governance in Late Capitalism", on top as the most linked reference to the rest of the citation networks. Moreover, the most cited journal in the journal co-citation network analysis is "Urban Studies", followed by "International Journal of Urban and Regional Research". In terms of centrality, the main journals in this field include the "International Journal of Urban and Regional Research" and "Urban Studies". Both journals hold the first two positions, indicating their significant influence in connecting the different publications and journals, which is highly valuable for researchers dealing with urban mutations. On the other hand, burst detections of keywords highlight "Eurasia" first, followed by "Urban Change" with a timeframe from 1987 to 1998. The strength burst citation keywords are mostly regions, ranking as follows: Europe, Asia, Western Europe, Far East, Sustainability, World, North America, and Urban Policy. These burst keywords are indicative of the characteristics of a specific period. The analysis of the data reveals that terms with high burst strength predominantly emerged in the early 21st century, particularly around the year 2000, albeit with limited durations. Conversely, terms such as "Urban Economy", "Globalization", "Geographic Factors", "Geography", and "Article" persisted over a longer period of 16 years. The most recent term, "Sustainability", remained relevant from 2019 to 2023. Although the concept of urban mutations dates back to the 1980s, it resurfaces around the beginning of this century in response to the evolution of urban sprawl problems and the appearance of new concepts such as "Urban Sprawl", "Smart Cities", "Urban Sustainability", "Urban Growth", and "Urban Regeneration". It should also be noted that the terms used by the CiteSpace labels under the LLR and LSI algorithms are "Urban transformation" and "Urban Change". Meanwhile, "Urban Mutation" did not appear in any analysis.

AUTHOR CONTRIBUTIONS

M. Bendeabbache performed the literature review, experimental design, analyzed and interpreted the data, prepared the manuscript text, and manuscript

edition. A.Khiari helped in the literature review and manuscript preparation. I. Maanser helped in the interpretation of data and the preparation of the manuscript text.

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CONFLICT OF INTEREST

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

PUBLISHER'S NOTE

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ABBREVIATION

<i>HSS</i>	Humanities & Social Sciences
<i>LBY</i>	Look back years
<i>LCA</i>	Life Cycle Analysis
<i>LLR</i>	Log-Likelihood-Ratio
<i>LRF</i>	Link retaining factor
<i>LSI</i>	Latent Semantic Indexing
<i>L/N</i>	Maximum link per node
<i>MI</i>	Mutual information tests
<i>PRISMA</i>	PRISMA: Preferred Reporting Items Systematic Review and Meta-Analysis
<i>SCI</i>	Science Citation Index
<i>SCI:</i>	Science Citation Index Expanded
<i>EXPANDED</i>	
<i>SSCI</i>	Social Sciences Citation Index
<i>SVM</i>	Structural Variation Mode
<i>WOS</i>	Web of Science

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ORIGINAL RESEARCH PAPER

The influence of pandemics in neighborhoods' public realms: Experts' point of view in light of social capital

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ABSTRACT

BACKGROUND AND OBJECTIVES: Neighborhoods' public realms get their sustainability from the presence of residents but the COVID-19 pandemic restricted the attendance of people. Hence, in light of the social capital paradigm may be revitalized the public realms. Adopting the approach of social capital and its components namely: social interaction, social participation, and spatial equity can improve the socio-physical characteristics of public realms during the outbreak of COVID-19. The extant study was conducted to evaluate the effect of COVID-19 on public realms of neighborhoods from the point of view of architecture and urbanism experts based on the components of social capital. This study aims to achieve strategies for planning and designing public realms by considering the COVID-19 condition, through which public spaces can be promoted in socio-physical dimensions.

METHODS: This research was quantitative with an inferential approach. The evaluation of 128 different nation scholars has been analyzed with an inferential approach and exploited LISREL8.8 and SPSS23 for their analysis.

FINDINGS: Findings indicate that the indicators of social interaction (Sig. <0.359) and spatial equity (Sig. <0.174) from most experts' views have the same structure and have a significant impact on the public realms of neighborhoods according to the pandemic. Moreover, there is a substantial difference in the social participation (Sig. >0.022) indicators between the two groups of experts.

CONCLUSION: Re-programming activity and restructuring physical (social interaction) developing and expanding green and open spaces and physical and functional flexibility (spatial equity) are the most important indicators for promoting public realms.

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INTRODUCTION

The advent of the COVID-19 pandemic has become a crisis with considerable and undeniable effects on the urban space, especially the public realms of residential neighborhoods. The social-spatial dimension in public spaces of residential neighborhoods has been highly affected by this disease. The decreased communication and social interactions among residents and the lack of presence in the physical space of the neighborhood will lead to their social isolation over time which, in turn, causes a lack of social capital in residential neighborhoods. The measures taken to control COVID-19 spread have influenced "social and spatial communications", which have also changed the "daily life practices" (Rose-Redwood *et al.*, 2020). The spread of the coronavirus has affected users' relationships with public spaces; especially the social interactions and attachment of people in these places have changed due to the imposed restrictions (Honey-Rosés *et al.*, 2020). In addition, COVID-19 will affect the planning and design of public spaces as well as the perception of users and behavior patterns that are formed there (Honey-Rosés *et al.*, 2020; Jasiński, 2020). In planning and designing the residential neighborhoods (socio-spatial dimension), particularly in the public realms, due to the advent of COVID-19 spread as a new challenge we are faced with an indispensable revision. Hence, COVID-19 disease may serve as an opportunity to expand interactions, social participation, and social health security in public spaces of residential neighborhoods. This study aimed to answer some questions:

A) To what extent can social capital as a solution for the crisis caused by the COVID-19 outbreak in public realms of residential neighborhoods?

B) Which components of social capital have the highest effect on public realms of residential neighborhoods from the experts' point of view, considering social capital as a solution in crisis?

C) What policies and strategies can be taken to design and plan public realms in the neighborhood considering the COVID-19 outbreak, and what can be the challenges?

The purpose of this paper is to examine the effect of COVID-19 on the public realms of residential neighborhoods from the expert's point of view based on the components and indicators of social capital to adopt policies and strategies for designing and

planning public realms of residential neighborhoods. Another objective of the present study was to improve interaction level, participation, and social capital among residents that have always been discussed in these areas and provide health in public realms. To do this, experts' assessment of public realms of residential neighborhoods regarding COVID-19 disease was examined. The manuscript survey was conducted from 7 November to 4 February 2020 to obtain the aforementioned objectives.

Literature review

Various studies have been conducted during the COVID-19 pandemic to examine the effect of this disease on urban space and the physical environment. The conducted studies can be divided into two categories:

A) Studies on physical elements of the built environment regarding COVID-19 (Hassan & Megahed, 2021; Pinheiro & Luís, 2020).

*B) Studies on some general factors, such as quality of life, well-being, and social capital concerning the urban environment, particularly public spaces during the pandemic, by consideration of two physical and psychological dimensions of health problems and individuals' behaviors in these areas (Mehta, 2020; Bian *et al.*, 2020), the most significant studies have been mentioned herein.*

Slater (2024) inspected the relationship between mental well-being and social capital in the UK during the COVID-19 pandemic. The results reported that the impact of social capital on the well-being of citizens could be achieved through 'social interactions and 'social networks. The components of social capital have a direct impact on mental health and life satisfaction. Taczanowska *et al.*, (2024) investigated the role of urban green spaces on the health and well-being of citizens in Vienna, Austria during the Covid-19 pandemic. Researchers point out that citizens' perceptions of open and green urban spaces during the epidemic period are different, according to their age. In addition, the results of this research reported that residents evaluated the relationship to urban green spaces as important for 'physical, mental and emotional health'. In this research, it has been reported that during the pandemic, adults have spent more time in the open and green spaces than the elderly, and they have also reported positive effects on their health, such as reducing depression and fear. In

another study, [Lee et al., \(2023\)](#) examined the impact of citizens' access to green space on mental health during the COVID-19 pandemic in the United Kingdom. The findings indicate that residents who have more and closer access to green spaces have experienced much less psychological distress. [Poortinga et al., \(2021\)](#) studied the role of public and private green spaces in the subjective health and well-being of UK citizens regarding the COVID-19 outbreak. The results suggest that public and private green space access plays a vital role in improving subjective health and well-being during the pandemic. [Pan et al., \(2021\)](#) examined the rate of COVID-19 outbreaks in 'Public Green Spaces' (PGS) in some areas of London. The results indicated that deprived areas demonstrated a higher possibility of infection spread even with moderate connectivity of the PGS. Furthermore, [Gao et al., \(2023\)](#) have investigated residents' access to urban space in American neighborhoods during the pandemic. Researchers reported that people living in urban neighborhoods use public parks more in comparison to rural areas. Residents used parks with a larger area and less density during the epidemic. However, the factor of distance and access to green spaces for residents plays a more fundamental role, especially for vulnerable groups. The scholars state that equal and proportional access of residents to urban green spaces can lead to health equality during the pandemic. Moreover, the authors pointed to the importance of 'social conditions' and 'infrastructures' in controlling COVID-19. In addition, [Hanzl \(2020\)](#) argues in a study that the expansion of green spaces, such as neighborhood parks, improves the quality of urban space and supports citizens' health during the COVID-19 pandemic. [Pinheiro & Luís \(2020\)](#) pointed to the vital role of a unique environment in public health. Hence, structural changes must be created in urban areas and buildings on two micro and macro scales during the COVID-19 pandemic. The authors pointed to five indicators used to change the spatial environment to prevent outbreaks:

- A) *street paths (sidewalks and cycling paths);*
- B) *public equipment (urban furniture);*
- C) *public transportation;*
- D) *green spaces;*
- E) *Information Technology.*

Moreover, [Hassan & Megahed \(2021\)](#) proposed several Configuration models and urban public seating that could be used in open spaces to protect

users' health during the COVID-19 pandemic. It should be noted that the proposed seating models were evaluated based on the specific microclimate, and all proposed options could decrease the risk of viral transmission in public open spaces. [Wray et al., \(2020\)](#) discussed challenges in public realms when coping with COVID-19 disease and its association with health. The authors argue that planning and design of public realms by considering the quality of spaces and some general issues, including social equity and health. This study suggests education-based measures in public realms and investment in designing and re-designing such spaces during the COVID-19 outbreak. In another study, [Mehta \(2020\)](#) argues that the COVID-19 outbreak has altered residents' sociability and social interactions, particularly in public spaces. Furthermore, it has been explained that public spaces during a pandemic can bring a cohesive relationship between residents by changing social distancing and behaviors. On the other hand, public spaces can lead to a healthier life for residents in the neighborhood. [Glover \(2021\)](#) explains that although COVID-19 has influenced social interaction in public spaces, neighborhoods have paid more attention to the point that providing walking facilities in the neighborhood can improve the interaction between neighbors during the COVID-19 pandemic. [Tseng et al., \(2024\)](#) have studied the impact of the pandemic on social capital among Chinese immigrants in Philadelphia. The results of this study indicate that the participation of residents in solving neighborhood problems has decreased. Also, on the other hand during the pandemic, cognitive social capital, such as a sense of belonging to the neighborhood and trust, has increased. Moreover, [Xie et al., \(2020\)](#) carried out a study on Chengdu, China citizens, who reported weak health status due to lack of sufficient social interaction and communication. Besides, Xie and colleagues introduced urban parks and large public spaces as appropriate solutions for increasing residents' social interaction and health during the COVID-19 pandemic. [Wu \(2021\)](#) evaluated the case study of Hubei, China, and pointed out that the COVID-19 outbreak is better handled in places where social capital is high. Findings indicated that some components, such as social networks at the contextual level, collective efficacy, trust, and individual level, could be effective during crises like the COVID-19 pandemic. [Bian et al., \(2020\)](#)

conducted a study in China and found that the higher the social capital, the more positive the effect of virus combat in both dimensions of behavior and quality of life. Moreover, the study introduced 'Intimate relations' and 'Informational diversity' as factors affecting social capital to cope with the pandemic. In addition, numerous applied studies have been done on health and social capital, indicating the effective relationship between these two variables. Muntaner *et al.*, (2000) introduced social communications as the social capital's component affecting the improvement or reduction of health. The high level of social capital improves health and solves the 'inequality' issue (Farrell, 2007). The changed social networks can increase the 'collective efficacy' of the neighborhood and improve the health of residents (Domínguez & Arford, 2010). Gan (2017) carried out a study to examine the effect of neighborhood social environment on older adults' physical and psychological health and found a strong relationship between neighborhood social environment and the psychological health of older adults. Miyamoto *et al.*, (2014) referred to 'supportive environment' and 'social relationships' between neighborhoods as interconnected social capital indicators. Moreover, there is a significant relationship between 'attachment to place,' as a social capital component, and 'physical and psychological' health. Findings indicated that non-participation in recreational activities and mistrust led to health problems. Carpiano (2007) found a direct relationship between social capital and health results and introduced 'neighborhood attachment' as the moderate variable between health and social capital. Accordingly, the higher the place attachment among residents, the higher the health risk due to more involvement in activities. It can be pointed out by discussing the literature review that social capital is one of the effective paradigms in responding to solving problems and the negative effects that crises such as COVID-19 have created in society. Most of the research has predominantly dealt with the impact of open and green spaces as a solution for improving the mental and physical health of people or discussed the social behavior of citizens in public realms during the COVID-19 pandemic. According to relevant literature, there is a research gap in this case since few studies have examined the impact of COVID-19 on public realms of residential neighborhoods, especially from the evaluative viewpoint of experts. Experts'

viewpoints can be significant because experts can bring the alterations closer to reality according to the existing conditions and complexity of components that are influential in public realms. In addition, fewer studies have addressed the role of the social capital paradigm that can bring the sustainability of public realms as a part of the daily life of the residents.

Theoretical framework

Social capital

Social capital is considered in different disciplines, such as 'social sciences,' with the potential of connecting different disciplines (Robison *et al.*, 2002; Lin, 2001). As a collective or potential asset, social capital is available through extensive social networks and resources. Since social capital includes a stable network of more or less institutionalized relations, it is assigned to the mutual recognition of one person or a group authenticating it (Bourdieu, 2005; Tavassoli & Mousavi, 2005; Krikken, 2013; Young, 2014; Burt, 2005). Social capital creates a structure to analyze the social impacts and increasingly investigate the 'social situation of person' and 'social environment features' (McClain, 2016). On a neighborhood scale, social capital is achieved only through social networks obtained from the continuous presence of people (Jacobs, 2013). Social capital can be introduced as an appropriate approach to connect residential neighborhoods' physical and social features. On the other hand, social capital can be used to solve the issues existing in the neighborhood. Social capital provides a "dynamic interaction" between the criteria above (Nikounam Nezami & Asadpour, 2021). Public spaces can create and develop social capital and affect welfare and health (Carmona *et al.*, 2008; Kohn & Kohen, 2004). Public spaces' potential improves two physical and mental dimensions of individuals' health. An appropriate public space can also improve individual satisfaction (Shaftoe, 2008). Hence, public realms must be designed so that users can do their activity in these realms besides sociability. In other words, the public realm is created by citizens' activities.

Components and indicators

A) *Social Interaction (SI)*: SI is one of the indicators of social capital, providing a metric to evaluate public realms and their sociability. Social interactions between residents of neighborhoods indicate the

social networks. Connection and relationships between neighbors living in a neighborhood increase trust levels and encourage them to achieve their goals in the environment (Nikounam Nezami & Asadpour, 2021). SI bring mutual dependence, trust, shared norms, and collective actions (Kleinhans, 2009). Social interactions are a core prerequisite of social networks and structures (Miltenburg, 2015). Social networks indeed explain the social interactions between residents of a neighborhood and increase well-being and quality of life (Unger & Wandersman, 1985). Social interactions are formed through social and collective events and the daily communication of residents in neighborhoods; also providing a context for the formation of social interactions will strengthen social networks and increase the presence of people in the place (Nikounam Nezami & Asadpour, 2021). Public areas can be considered an appropriate context for social interactions and social networks that expand individuals' sense of belonging (Tajbakhsh, 2017; Habibi, 2003).

B) Social Participation (SP): SP creates an opportunity for communication between residents in the neighborhood, which can affect the health, and well-being of the residents. SP is a component that depends on the 'experiences' and 'attributes' of residents. From this point of view, SP can have positive and negative effects on the well-being and health of residents (Satariano, 2021). Dynamic interactions and relationships between residents lead to participation. SP is one of the key dimensions of social capital in residential neighborhoods that strengthens the decision-making process of planners in these areas. Moreover, the participation of residents in the process of planning and designing areas of residential neighborhoods, because it takes into account the 'expectations' and 'preferences' of residents, can cause residents to connect more with the environment and, as a result, increase the quality of these areas (Nikounam Nezami & Asadpour, 2021). Participation creates the potential for various opportunities and services for residents (Bailey, 2010). Participatory approaches are based on social capital resources (Selman, 2001). Accordingly, the higher the social participation of residents, the higher the social capital (Ziersch et al., 2011). Residents' participation in public areas of neighborhoods is a maintenance mechanism of these places (Nikounam

Nezami & Asadpour, 2021).

C) Spatial Equity (SE): the concept of SE is a subcategory of social equity, arguing that residents living anywhere must behave equally (Tsou et al., 2005). SE in the neighborhood is done by providing suitable access to services and infrastructures to meet residents' needs. SE attracts residents to public realms and paves the way for residents' presence in these spaces (Nikounam Nezami & Asadpour, 2021).

Each of the components of social capital is an important factor in the emergence and sustainability of social capital indicators in the public realm. For instance, trust between residents contributes to purposeful engagement among users in the environment, and social networks and common values increase the communication of residents in place. Indicators of social capital (i.e., trust, social networks) can improve social and spatial components, such as SI and SP (social dimension) and SE (physical dimension) in the neighborhood. According to the points mentioned above, a model can be designed for improvements and sustainability of public realms in residential neighborhoods based on the social capital formed in the neighborhood (Fig. 1). The conceptual model of this study has two merits:

A) In the proposed model, each indicator has an internal connection with each other;

B) This model provides an integrated process and structural solution in promoting the public realms during the COVID-19 epidemic.

For instance, increasing the SI of residents in the public realms can reinforce individual participation in public spaces such as the engagement of residents in events, as well as decision-making about the physical and social changes in public spaces during the pandemic period. Furthermore, the SE component can also be a ground for social interactions, whereas quarantine conditions have reduced the presence of residents in the public realms; in other words, equal access to open and green spaces in the neighborhood, as well as a balanced combination of services, can attract residents and reinforce their presence in the public space. Therefore, it can be mentioned that in the conceptual model, all the components are linked together to solve the critical that COVID-19 has created in the public realm; it can be assumed that the conditions for the sustainability of the public realm can be provided by social capital components.

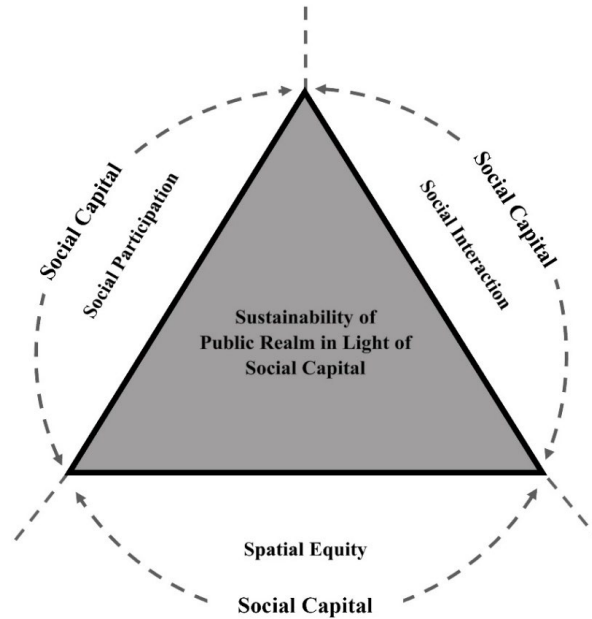


Fig. 1: Conceptual model of social capital improvement in public realms during the crisis

MATERIALS AND METHODS

The present study is quantitative with an inferential approach. Furthermore, this manuscript contains four steps (Fig. 2); in the first stage, the data collecting was done using documentary and bibliographic studies to create a conceptual framework and recognize the components and indicators of social capital.

Afterward, in the second step, a questionnaire was designed (with close questions on the Likert scale of very low to very high) based on three components of social capital (Table 1), including SI (questions 1 to 15), SP (questions 16 to 21), and SE (questions 22 to 31) in public realms. By the conceptual model of promoting social capital in public realms (Fig. 1), the questions examined the impact of factors of all three categories of the mentioned components on public realms during the COVID-19 crisis. In addition, the pilot questionnaire was distributed among Iranian experts (urban planning, urban design, architecture, and landscape architecture) on 7 November, and then the completed questionnaires were collected on 7 December 2020. After the validity and reliability of collected data from Iranian experts were assessed, the questionnaires were sent to international experts in Asia (Japan, Lebanon, Pakistan, and the United Arab Emirates), Europe (experts from the UK, Netherlands, Norway, Turkey, and Sweden), Africa (Egypt and

Algeria), and the USA (USA, Canada, Colombia, and Brazil) within a two-month interval from 4 December to 4 February 2020. It should be noted that web-based online form-builder software was exploited to prepare the questionnaires, and then the questionnaire link was sent to the academic email address and personal page of social media (ResearchGate and LinkedIn) of experts ($n=452$) two times. To select professionals, a list of international architects, urban planners, and urban designers was prepared. Among them, some experts were chosen according to interest areas inclined to social approaches or urban space analysis; particularly scholars in the social capital domain were intended. Moreover, the reason for choosing experts to evaluate the influence of the pandemic on public realms is that experts can better analyze and evaluate public realms due to their approaches, mastery, and comprehensive knowledge of components and variables. Therefore, experts' viewpoints might mitigate the problems and shortcomings in public realms during the pandemic.

Furthermore, in the second step, all data from 50 Iranian and 78 international experts were integrated and analyzed. It should be noted that the frequency of academic degrees of respondents was as follows: Ph.D. students (25%), assistant professors (24%), professors (20%), instructors (17%), and associate

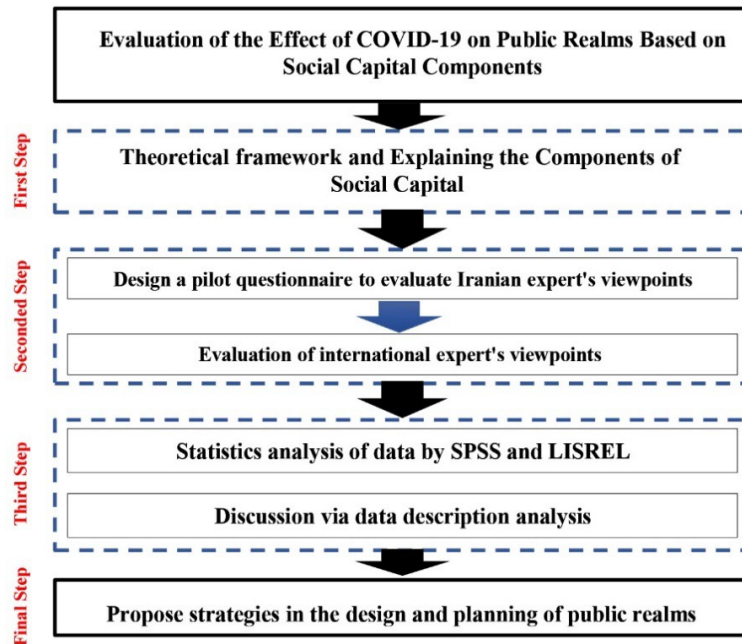


Fig. 2: Research process

professors (14%). In addition, 40% of respondents were architects, 27% were urban planners, 27% urban designers, and 6% were landscape architects. In the extant study, 52% of respondents were men, and 47% were women; furthermore, the highest and lowest relative frequencies of the age of respondents equaled 30-40 (41%) and 20-30 (16%). Moreover, in the third stage, confirmatory factor analysis was exploited to test the validity of the questionnaire; the content analysis was done through LISREL8.8 and SPSS23 software. Thirty-one questions (Q1 to Q31) were designed for three components, including SI, SP, and SE. The items were inserted into the LISREL (Linear Structural Relation) software. The standard estimation mode of the model (Fig. 3) as the primary output, measures the factor loads for each of the paths of the model. The factor load shows the strength of the relationship between the component (latent variable) and the items (questionnaire questions/observed variables). If the value of this number is less than 0.3, the relationship is weak and ignored, and if the factor load is between 0.3 to 0.6, the relationship is acceptable, if it is more than 0.6, the relationship will be considered very favorable. Hence, as seen in Fig. 3, question 4 (SI component) with a factor load of 0.63, and also questions 17 and 18 (SP component) have a very favorable relationship

with their component with a factor load of 0.64 and 0.63, respectively. In addition, the rest of the items have a factor load between 0.3 and 0.6, which reports an acceptable relationship.

In addition, the significant coefficient model shows the t value for each question as the second output of the model (Fig. 4); the t value of the path coefficient must be greater than 1.96 for the relationship between each of the questions and the desired components to be significant (Vieira, 2011). Therefore, considering that the value of t for each question is more than 1.96 in the model of significant coefficient (Fig. 4), it can be stated that the relationship between each of the questions and the research components is significant and so the items (questionnaire questions) are suitable explanations for the components. Consequently, the results of the model outputs in two modes of standard estimation and the significance coefficient of confirmatory factor analysis show that the items (questionnaire questions/observed variables) have measured the components well. Furthermore, to assess the reliability of the questionnaire, the collected data were imported to SPSS (Statistical Package for the Social Sciences) software and Cronbach's alpha method was used. The alpha coefficient equaled 0.876 (>0.70), indicating acceptable reliability of the questionnaire. After that, a one-way ANOVA (Analysis of Variance)

Table 1: Survey questions according to the components of social capital

Component	Question
SI	1. To what extent do you think strengthening public and street arts in the public realm can stabilize our visual experiences in the face of an epidemic?
	2. To what extent do you think the development of open and green spaces in neighborhoods is a solution to maintain and establish social interactions among residents in the event of an outbreak?
	3. Given the prevalence of the disease, to what extent should the street landscape be redesigned to improve social interactions?
	4. To what extent do you think pedestrian access networks need to be redesigned to achieve social interactions at the neighborhood level?
	5. To what extent can semi-private spaces be considered a potential element in social interaction during a crisis compared to public spaces in residential neighborhoods?
	6. Given the prevalence of the epidemic, to what extent should the presence of vehicles at the neighborhood level be limited and cycling loops and pedestrian networks be allowed to increase social interaction?
	7. To what extent can the increase in online services as well as the use of new communication technologies lead to a reduction in the presence of residents in the public realm?
	8. To what extent can microclimate provision in the public realm increase the attraction of residents to these places, given the prevalence of the epidemic?
	9. To what extent can arranging furniture and structuring it in public spaces based on social distance lead to a greater presence of residents and the preservation of social interactions?
	10. To what extent can strengthening the dialectic inside and outside the public realm visually and physically increase the communication of the residents in the neighborhood, given the current situation?
	11. Given the prevalence of COVID-19, how necessary is it to change the physical structure of the public realm to establish social interactions?
	12. Given the outbreak of the coronavirus, to what extent can measures to strengthen the soft edges at the neighborhood spatial level improve social activity among residents?
	13. To what extent do you think programming activities should be re-evaluated to prevent population congestion in the public realm?
	14. To what extent can the enhancement of the visibility of public spaces encourage neighborhood residents to attend these spaces, compared to the conditions before the outbreak of coronavirus disease?
	15. To what extent can street shops and open shops in neighborhoods be able to increase social interaction, given the prevalence of epidemics?
SP	16. To ensure the physical security of residents in public spaces, to what extent should the management of these spaces be changed by adopting policies such as enforcing traffic time limits or limiting the presence of users?
	17. According to the COVID-19 disease, to what extent can NGOs be effective in applying structural changes to user behavior in the public realm?
	18. To what extent do you think participation of residents in the public realm can benefit them socio-economically, given the conditions of the virus epidemic?
	19. To what extent can the presence of NGOs as observers in the public realm improve the conditions of use of arenas, given the prevalence of the disease?
	20. To what extent can policies such as traffic hour limits or limiting the presence of users be effective in maintaining the psychological security of residents in public spaces?
	21. Due to the crisis, to what extent should the participation by designers and residents both when designing public spaces and during post-occupancy be a priority from your perspective?
SE	22. Given the circumstances that COVID-19 has created in the public realm of residential neighborhoods, to what extent is there a need to revise planning, standards, and per capita?
	23. To what extent can the abandoned spaces that exist at the neighborhood level be considered as a potential for creating public space and open spaces in times of crisis?
	24. In your opinion, to what extent should balance and equal access to public spaces be given priority in the planning of residential neighborhoods, given the existing conditions?
	25. To what extent should increases in services provided by municipalities and other government organizations in public spaces be considered, given the prevalence of COVID-19?
	26. To what extent can street shops and open shops in neighborhoods play a proportionate role in meeting the needs of residents, given the prevalence of the epidemic?
	27. To what extent can flexibility in the physical activity and structure of public spaces be considered as a solution to the crises?
	28. To what extent should socio-economic potentials in the public realm be actively and increasingly addressed?
	29. To what extent should residents' access to health services in the public realm be considered in planning?
	30. To what extent should the structure of public commutes be re-structured given the outbreak of the Coronavirus?
	31. In your opinion, considering the spread of the Coronavirus, to what extent can development and increases in local green spaces maintain and improve the health conditions of the residents?

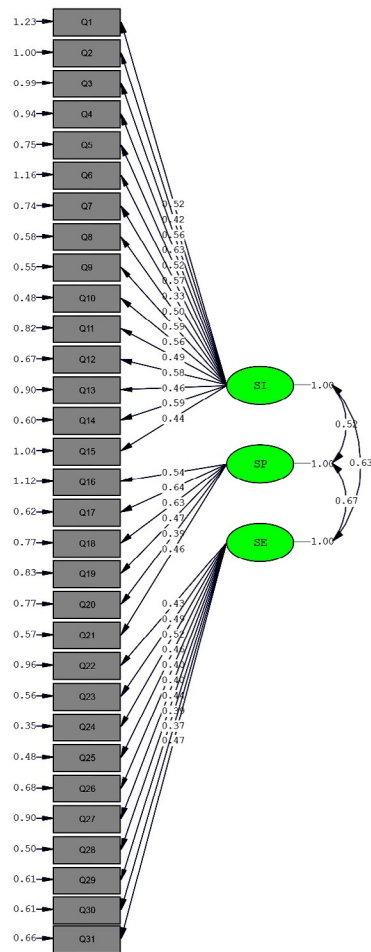


Fig. 3: Model of confirmatory factor analysis of variables in standard estimation mode

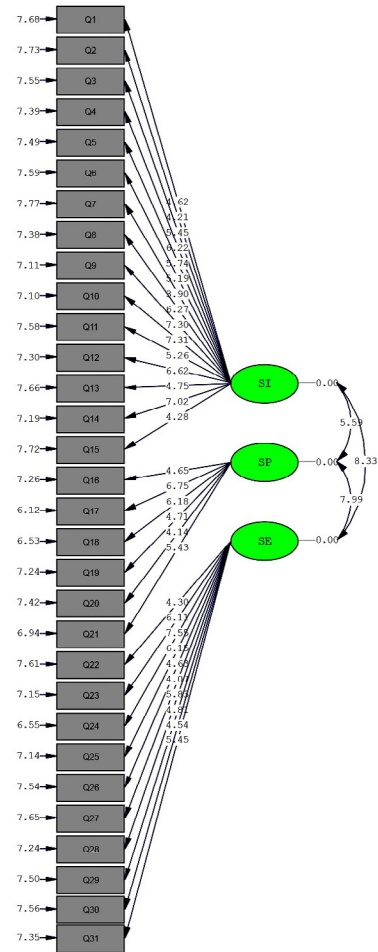


Fig. 4: Model of confirmatory factor analysis of variables in the significant coefficient mode

was used for expert groups based on their academic ranks (Lecturer, Ph.D. student, assistant professor, associate professor, and professor) to examine the significance of variables. Regarding social interactions and spatial equity (Tables 2 and 3), equality of means was approved in five groups of experts. Since the significance value was greater than 0.05, there was not any statistically significant difference between experts.

Besides, according to the ANOVA of SP, the equality of means among five groups of experts was rejected (Table 4). According to the reported significance value (<0.05), there was at least a significant difference between one of the experts' groups and others. Hence, Hochberg's test (Table 5) was used to identify the difference between the groups of experts. After performing that test, the highest difference was seen

between Ph.D. students and assistant professors. Thereby, there is no significant difference between the experts' evaluations except for the group of doctoral students and assistant professors in the component of SP, and the answers of all groups can be considered to be almost in the same direction. In addition, in the third step, the descriptive analysis was performed based on the point that most experts agree on, to present the findings. However, in the final stage according to the findings, the strategies for improving neighborhoods' public realms were proposed.

RESULTS AND DISCUSSION

As mentioned in the previous section, the responses of the experts to the questions were according to the five-point Likert scale from very

low to very high. Data description was done based on the grade that the majority of experts agreed on (Table 2). In terms of the first component (social interactions), 36% of professionals, in their evaluation have pointed out that the physical structure of public realms should be changed to increase social interactions in these spaces. As Mehta

(2020) points out in his studies, due to the COVID-19 pandemic, changes can be considered in the social space due to the distances and social customs that have emerged in social interactions. Most of the experts also answered another question of this component (41%), arguing that the development and expansion of open green space must be considered in

Table 2: ANOVA of experts in terms of social interaction

	Sum of Squares	degrees of freedom (df)	Mean Square	F	Sig.
Between Groups	316.457	4	79.114	1.101	.359
Within Groups	8837.418	123	71.849		
Total	9153.875	127			

Table 3: ANOVA of experts in terms of spatial equity

	Sum of Squares	degrees of freedom (df)	Mean Square	F	Sig.
Between Groups	157.114	4	39.278	1.618	.174
Within Groups	2985.761	123	24.274		
Total	3142.875	127			

Table 4: ANOVA of experts in terms of social participation

	Sum of Squares	degrees of freedom (df)	Mean Square	F	Sig.
Between Groups	162.194	4	40.549	2.976	.022
Within Groups	1675.681	123	13.623		
Total	1837.875	127			

Table 5: Multiple comparisons of social participation

Hochberg						
(I) Expert	(J) Expert	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Lecturer	PhD student	-.88636	1.02224	.992	-3.7979	2.0251
	Assistant Professor	2.05718	1.02894	.381	-.8734	4.9877
	Associate Professor	1.58586	1.17307	.854	-1.7552	4.9269
	Professor	.74364	1.07897	.999	-2.3294	3.8167
	Lecturer	.88636	1.02224	.992	-2.0251	3.7979
PhD student	Assistant Professor	2.94355*	.93016	.019	.2943	5.5928
	Associate Professor	2.47222	1.08747	.218	-.6250	5.5695
	Professor	1.63000	.98523	.645	-1.1761	4.4361
	Lecturer	-2.05718	1.02894	.381	-4.9877	.8734
	PhD student	-2.94355*	.93016	.019	-5.5928	-.2943
Assistant Professor	Associate Professor	-.47133	1.09377	1.000	-3.5865	2.6439
	Professor	-1.31355	.99217	.869	-4.1394	1.5123
	Lecturer	-1.58586	1.17307	.854	-4.9269	1.7552
	PhD student	-2.47222	1.08747	.218	-5.5695	.6250
	Assistant Professor	.47133	1.09377	1.000	-2.6439	3.5865
Associate Professor	Professor	-.84222	1.14096	.998	-4.0918	2.4074
	Lecturer	-.74364	1.07897	.999	-3.8167	2.3294
	PhD student	-1.63000	.98523	.645	-4.4361	1.1761
	Assistant Professor	1.31355	.99217	.869	-1.5123	4.1394
	Associate Professor	.84222	1.14096	.998	-2.4074	4.0918

*. The mean difference is significant at the 0.05 level.

neighborhoods to create and keep social interactions during a disease outbreak. [Hanzl \(2020\)](#) in their study has considered the development and expansion of open and green space concerning the epidemic as a solution. It can be mentioned that green and open spaces due to grounding opportunities for increasing social interactions and physical activities of residents in neighbourhoods can positively affect mental and physical demands during the pandemic.

Most professionals have stated that semi-private spaces have more potential for establishing social interactions than public spaces in neighborhoods. In other words, according to the conditions created by COVID-19, social interactions can take place mostly in semi-private spaces that have less population density than public spaces. Moreover, in the other question, experts (45%) introduced structured furniture layouts in open spaces based on the social distancing rules affecting social interactions and the presence of residents in these spaces. As mentioned in the background of research in the studies of [Pinheiro & Luís \(2020\)](#) as well as [Hassan and Megahed \(2021\)](#), according to the conditions of COVID-19, changes should be considered in the configuration of public space furniture. In the descriptive analysis of the second component i.e., SP, 39% of experts on the improvement of public spaces, believed that the presence of civil groups and institutions as supervisors in these areas could be effective. In addition, 40% of scholars introduced the participation of designers and residents in public realms both within the design process and after an occupation as the priority of planning and design during the COVID-19 pandemic. In terms of the spatial equity component, 46% of experts mentioned the abandoned spaces as the potential that be used to create open spaces during the crisis. In addition, 43% of experts introduced balanced and equal access to open spaces as a priority in planning residential neighborhoods. On the other hand, 48% of experts found the open and street stores with appropriate functions to meet the daily needs of residents during the COVID-19 pandemic. Open spaces can help residents in two ways; they can facilitate recreational activities to increase social dynamics or provide amenities and green spaces to promote environmental quality. However, from the viewpoint of 41% of experts, flexibility in the activity and spatial structure of public space can be used to respond to the crisis. Activation of economic and social potential must be

highly considered in assessments associated with public realms. As [Haines et al., \(2011\)](#) pointed out in their studies; paying attention to the socioeconomic characteristics of the neighborhood can be effective in the health dimension. Another significant point of SE is the available health services in public realms for residents so experts consider it a critical case in the design of residential neighborhoods. Moreover, 54% of scholars on the aspect of SE have declared that the access of residents to health services should be considered in the planning of public realms to a large extent. The aforementioned issue can be taken into consideration by allocating micro spaces as well as the location of health equipment and services in the planning of public realms in spatial planning. According to 49% of experts, the development and expansion of green space is an effective indicator of SE that must be considered in keeping and improving physical and mental conditions during the COVID-19 outbreak. [Poortinga et al., \(2021\)](#), point out that green spaces have a significant impact on the promotion of people's health. In addition, professionals (50%) argued that public commutes structures must be altered. Considering the social distancing adopted during the pandemic, the change and expansion of public commute infrastructure at the level of neighborhoods can strengthen the presence of arenas. For instance, the development and strengthening of pedestrian and bicycle lanes that are connected to the traffic networks of public spaces can maintain the vitality of these places. It should be mentioned that what put the findings of the current research concerning the problem of COVID-19 and what makes the findings differ from the results of peer studies could be explained in three dimensions. Firstly, the paradigm of social capital has been expressed as a pivotal solution to face the COVID-19 crisis in public realms of residential neighborhoods, a problem that has led to the reduction of residents' presence in public spaces. Secondly, in the theoretical framework proposed in this research, scholars have examined components of social capital that these components can strengthen the socio-physical dimension more than other components of social capital in public realms during the epidemic. Thirdly, the evaluation of experts has been done according to the conditions that COVID-19 has created in the public realm. Therefore, it can be claimed that the collected data have thoroughly discussed the issue of COVID-19 in public spaces in the light of social capital,

the analyses and findings are in the direction of the sustainability of public realms during the outbreak of COVID-19. Furthermore, based on the findings, the examined items, and the analyses obtained from the evaluative viewpoint of experts indicated, that no significant difference was observed between the components, except for the social participation in the group of Ph.D. students and assistant professors. The mentioned issue can be assessed in several dimensions:

A) The indicators expressed in social interactions and spatial equity have similar structures and frameworks (as a general regulation in public spaces) from many different national experts. Hence, these components can be used as a response to a crisis such as the COVID-19 pandemic to make public realms of residential neighborhoods sustainable.

B) As there was a significant difference between experts when evaluating SP, the difference might stem from the definition of the concept, levels, and

Table 6: Descriptive statistics

	Grade 1 (Very Low)	Grade 2 (Low)	Grade 3 (Medium)	Grade 4 (High)	Grade 5 (Very High)	Mean	Std. Deviation
Q1	11%	16%	23%	34%	16%	3.2813	1.22273
Q2	4%	7%	12%	36%	41%	4.0391	1.08245
Q3	6%	10%	28%	32%	24%	3.5859	1.14002
Q4	4%	12%	14%	37%	33%	3.8125	1.15527
Q5	2%	7%	22%	38%	31%	3.8828	1.00879
Q6	7%	11%	17%	34%	31%	3.7187	1.21628
Q7	2%	1%	21%	30%	46%	4.1719	.92310
Q8	2%	7%	34%	39%	18%	3.6484	.91005
Q9	2%	6%	16%	45%	31%	3.9609	.95078
Q10	2%	9%	26%	48%	15%	3.6641	.88981
Q11	2%	11%	27%	36%	24%	3.6719	1.02803
Q12	3%	9%	33%	36%	19%	3.5781	1.00086
Q13	3%	8%	17%	38%	34%	3.9219	1.05449
Q14	2%	10%	25%	44%	19%	3.6641	.97429
Q15	5%	11%	21%	38%	25%	3.6797	1.10784
Q16	9%	16%	25%	33%	17%	3.3516	1.18780
Q17	2%	13%	28%	38%	19%	3.5781	1.01647
Q18	5%	10%	23%	40%	22%	3.6562	1.08270
Q19	3%	7%	23%	39%	28%	3.8203	1.02284
Q20	3%	5%	31%	41%	20%	3.6953	.96030
Q21	1%	3%	19%	37%	40%	4.1172	.88399
Q22	3%	9%	18%	36%	34%	3.8984	1.07102
Q23	2%	2%	15%	35%	46%	4.2187	.89564
Q24	0%	2%	15%	40%	43%	4.2344	.78854
Q25	1%	4%	12%	47%	36%	4.1406	.82990
Q26	3%	2%	20%	48%	27%	3.9297	.91517
Q27	3%	6%	14%	36%	41%	4.0703	1.02860
Q28	0%	4%	22%	42%	32%	4.0234	.83680
Q29	1%	3%	12%	30%	54%	4.3281	.87042
Q30	1%	4%	19%	26%	50%	4.2109	.93617
Q31	1%	4%	10%	36%	49%	4.2891	.86172

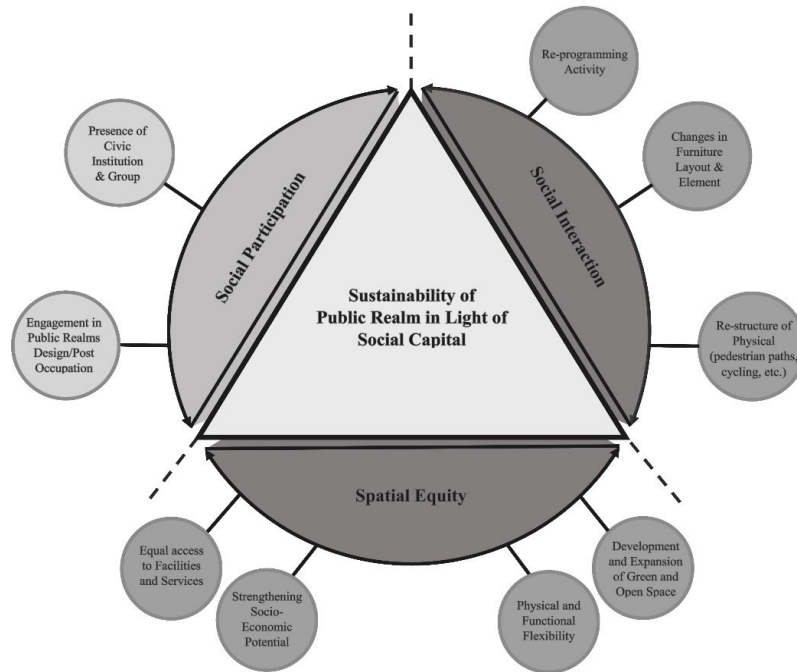


Fig. 5: Conceptual model of sustainability of public realms in light of social capital based on finding

generalization process of SP in public realms from the viewpoint of many different national scholars. Therefore, the adoption of general rules for this component must be examined based on the public areas to present some solutions.

C) Considering that, the difference in the participation component is only in two groups of experts and there is no difference between other experts in this component can be relied on important findings. In addition, some strategies can be proposed in the planning and designing of public realms of residential neighborhoods based on the social capital's components during the COVID-19 pandemic:

A) SE

Conversion of the abandoned spaces in the neighborhood to open public spaces is a potential strategy that provides the field for the presence and sociability of residents and the participation of users in the formation and application of these spaces. Balanced and equal access of residents to public realms, services, and health facilities in the neighborhood must be taken as a policy in the design of residential neighborhoods to make SE. Consideration of flexibility strategy in physical structure and public realm activity can be considered an option that brings an appropriate

and diverse capability in realms during crises. Hence, the predetermined flexibility of space during different conditions makes it capable of responding to the considered function. Street and open stores can create a socioeconomic potential for residents and a suitable performance to meet the daily needs of residents during the pandemic. Development and expansion of open green space in a residential neighborhood can serve as public spaces that provide the mental and physical health of residents. In other words, this can be taken as an effective strategy to improve the public health of residents during the COVID-19 pandemic.

B) SI

The COVID-19 outbreak has changed the citizens' behaviors in public areas; hence, the physical configuration must be revised to increase the presence of residents considering the features and conditions of the context and behaviors of residents. Increased access to sidewalks and cycling paths, improved visual and physical connection of public areas, and changed type and layout of elements, and furniture used in public areas are some options that keep social interactions based on the structure of public spaces. It is possible to improve the relationship between neighborhood residents and

improve their mental and physical health by changing activities and making the public areas eventful during the pandemic. Public spaces can be designed based on collective activities considering crisis conditions, and public street art can be strengthened to improve interaction and relationships between residents.

C) SP

Civil institutions and groups as supervisors in public areas and making such non-profit institutions aware of critical conditions are effective factors used in public spaces to increase cohesion and participation among residents. Participation of residents in decisions made on the design and formation of public areas of neighborhoods and keeping these spaces can serve as strategies for SP among residents in public realms during the pandemic. Conforming to the mentioned strategies, a conceptual model (Fig. 5) of effective indicators has been presented from the evaluation of the specialists to promote social capital in the public realms of residential neighborhoods according to the crisis conditions.

CONCLUSION

Neighborhoods' Public realms play a pivotal role in which the life quality of residents. These realms get their sustainability from the presence of the community members. However, during the COVID-19 pandemic, due to the adoption of restrictions by policymakers and health-related issues, public realms faced a decrease in the presence of residents. Adopting a social capital approach in the public realms of neighborhoods can bring residents closer to the goals of the responsive environment and help these spaces to be sustainable; in other words, social capital can be recognized as a solution to the socio-physical promotion of the public realms. Thereby, the paradigm of social capital can be considered effective in livability and revitalizing public realms. The contribution of the present article can also be seen as the confirmation of the issue that social capital, through the components can eradicate the social isolation of residents, which is one of the consequences of the spread of COVID-19. In this study, three components of social capital in the public realms of residential neighborhoods have been explained, which include: A) SI; B) SP, and C) SE. The evaluation performed indicates that the components of SI and SE as components affecting the public realms of residential neighborhoods have a common configuration that by applying, practical policies and strategies in design and

planning, can obtain the socio-physical sustainability of public realms. However, the component of SP, like other components of social capital, according to the findings, has a significant difference in the expert's evaluation (between two groups), which may be owing to dissimilar definitions and processes of SP from the expert's approaches. Overall, experts' views towards each of the three components are structurally related to each other and this paradigm can strengthen the presence and relations of residents in the public realms and achieve the goals of these spaces during the crisis. Moreover, based on the findings of this manuscript, it can be stated that for the public realm sustainability in residential neighborhoods in light of social capital components, some indicators should be taken in design and planning. For instance, re-programming and re-structuring of physical attributes should be considered. Also, the participation of civic organizations and the engagement of residents in the design process of public realms should be taken into account. Besides, some measures should be taken to expand open and green spaces, equal access to facilities, and flexibility in functional and physical characteristics. This study faced some constraints, such as a lack of access to all experts in the design of public areas to achieve and scrutinize extensive results. Further studies can be done on public areas of neighborhoods based on components and indicators of social capital from the viewpoint of residents regarding contextual conditions. On the other hand, comparative induction can be done before and after the pandemic. It is also suggested that further studies assess components improving social capital in public realms of different neighborhoods regarding their social classification and compare them. The results obtained from these studies can play an effective role in improving the quality of residential areas regarding critical conditions, such as the COVID-19 pandemic.

AUTHOR CONTRIBUTIONS

A. Asadpour performed the literature review, and experimental design, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. H. Nikounam Nezami performed the experiments and literature review, compiled the data, and manuscript preparation.

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CONFLICT OF INTEREST

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

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ABBREVIATIONS (NOMENCLATURE)

PGS	Public Green Spaces
ANOVA	Analysis of Variance
SI	Social Interaction
SP	Social Participation
SE	Spatial Equity
Sig	Level of significance
df	degrees of freedom
LISREL	Linear Structural Relation
SPSS	Statistical Package for the Social Sciences

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ORIGINAL RESEARCH PAPER

Statistical analysis based on a two-staged SEM-SVM approach for environmental noise annoyance prediction and identification of influencing factors

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ABSTRACT

BACKGROUND AND OBJECTIVES: Noise pollution is an environmental stressor that is mainly caused due to heavy transportation in urban scenarios. Traffic noise is a growing concern in urban environments, impacting public health and well-being. As urbanization expands, understanding and mitigating traffic-induced noise annoyance becomes increasingly critical. This study aimed to develop a machine-learning model for predicting traffic-induced noise annoyance in Riyadh, Saudi Arabia. The research explored the influence of factors like demographics, noise characteristics, and traffic conditions on noise annoyance.

METHODS: A survey was conducted at 21 locations in Riyadh, collecting data from 928 participants. The survey included questions on demographics (gender, age, education, marital status, profession), traffic conditions (traffic flow), and noise perception (transportation noise, noise sensitivity, perceived noisiness). The sampling method employed was a combination of stratified and random sampling. Stratified sampling was used to ensure that various demographic segments (e.g., different age groups, genders, and education levels) were proportionately represented in the survey. Structural Equation Modeling was used to analyze the collected data and identify factors significantly affecting noise annoyance. These significant factors were then used as input variables for a Support Vector Machine model designed to predict noise annoyance. The performance of the Support Vector Machine model was evaluated using Root Mean Square Error, Mean Absolute Error, and R-squared.

FINDINGS: The Structural Equation Model analysis revealed that gender, age, education level, traffic flow, noise from traffic, and individual noise sensitivity were significant contributors to noise annoyance. The developed Support Vector Machine model achieved a high level of accuracy with a root mean square error of 1.416 and a coefficient of determination of 0.90. Noise sensitivity emerged as the most crucial factor influencing noise annoyance.

CONCLUSION: This study demonstrates the effectiveness of machine learning, specifically the Support Vector Machine, in predicting traffic-induced noise annoyance. The findings highlight the importance of both individual characteristics and environmental factors in noise perception and can be valuable for urban planning and noise mitigation strategies, promoting a more noise-resilient city environment. For the community, urban planners and policymakers can use these findings to design silent areas by implementing noise barriers, optimizing traffic flow, and enforcing stricter noise regulations.

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INTRODUCTION

Noise pollution is one of the major environmental stressors that adversely impacts human health, well-being, and quality of life (Gupta *et al.*, 2018). It originates from various sources such as transportation (road, air, and rail), construction, industrial activities, and recreational pursuits (Tiwari *et al.*, 2023; Zengin *et al.*, 2020). In Saudi Arabia (KSA), environmental noise, particularly from traffic, has emerged as a persistent issue (Al-Ghonamy, 2010; Al-Ghonamy, 2009; Zytoon, 2016; AlSaleem *et al.*, 2023; PME, 2015). This can be attributed to the rapid development and expansion of cities, along with a substantial increase in the population, leading to higher demands for transportation facilities (Al-Ghonamy, 2009). As a result, major roads in cities like Jeddah frequently witness traffic volumes exceeding 300,000 vehicles per day (Elshorbagy, 1999). In response to this growing concern, the Presidency of Meteorology and Environment (PME) took action from 2012 onwards. They introduced new Saudi standards for environmental noise, which included guidelines for community noise levels during daytime, evening, and nighttime. These standards were categorized based on the sensitivity of the area (PME, 2015). Moreover, noise pollution can interfere with daily activities, disrupt communication, and contribute to social isolation (Singh and Davar, 2004). As urbanization increases and population expansion takes place, the prevalence of noise pollution escalates, necessitating concerted efforts to mitigate its adverse effects and safeguard public health and tranquility (Bronzaft and Hagler, 2010). Effective management strategies encompassing regulation, urban planning, technological innovations, and public awareness campaigns are imperative to address the multifaceted challenges posed by noise pollution in contemporary societies. Recent studies have indicated that excessive noise exposure can lead to a myriad of sleep disturbances, hypertension, cardiovascular disease, stress, hypertension, stroke, diabetes, feelings of annoyance, and cognitive impairment (Shamsipour *et al.*, 2022; Hemmat *et al.*, 2023; Garg, 2022). Noise annoyance is demarcated as a sensitive sign of discomfort, resentment, dissatisfaction, and offense (Hegewald *et al.*, 2020; Tiwari *et al.*, 2023, Stansfeld *et al.*, 2021). A lot of investigations were carried out to evaluate the feeling of annoyance caused by acoustical and non-acoustical

factors (Kim *et al.*, 2012; Bravo-Moncavo *et al.*, 2019; Das *et al.*, 2022; Gilani *et al.*, 2021; Morihara *et al.*, 2022). Sound level frequency, exposure period, Noise source, and the recipient's psychological and internal processes play a major role in the assessment of noise annoyance (Ouis, 2001; Jakovljevic *et al.*, 2009; Fyhri and Klæboe, 2009). As urbanization accelerates, particularly in rapidly growing cities like Riyadh, Saudi Arabia, understanding and mitigating noise pollution becomes increasingly imperative. Riyadh, the capital and largest city of Saudi Arabia, experiences considerable urban development and population growth, leading to elevated levels of noise pollution originating from various sources such as traffic, construction, and industrial activities. In the context of developing countries, the utilization of advanced technologies such as machine learning presents a promising approach for predicting and managing traffic-induced noise annoyance levels. Most of the researchers have used the Multiple Linear Regression model and Artificial Neural Network model for the determination of noise levels (Ranpise *et al.*, 2021; Nourani *et al.*, 2020) but rarely any studies have reported the use of a Support Vector Machine (SVM) in the prediction of noise annoyance. Machine learning models, leveraging complex datasets and complex algorithms, have demonstrated remarkable capabilities in discerning patterns and making predictions in diverse applications (Jordan and Mitchell, 2015). This study presents a machine learning-based framework known as an SVM tailored for the prediction of noise annoyance in Riyadh city, Saudi Arabia. The applicability of the SVM model is widely used in a lot of domain areas such as bankruptcy, bearing life, air pollution, and noise levels (Min and Lee, 2005; Yan *et al.*, 2020; Leong *et al.*, 2020; Tiwari *et al.*, 2022). The SVM is robust against overfitting, especially for high-dimensional data, and can effectively handle non-linear relationships using various kernel functions. SVMs are less sensitive to outliers and aim for a global optimization solution, aided by their regularization parameter for fine-tuning (Yan *et al.*, 2020; Leong *et al.*, 2020; Tiwari *et al.*, 2022). Applying the SVM model to forecast noise annoyance levels can offer valuable insights for city planners, policymakers, and residents alike, facilitating targeted interventions and strategies to mitigate and control the adverse effects of noise pollution on respondents. By integrating acoustical

and non-acoustical factors, with residents' subjective assessments of noise annoyance, the SVM model aims to accurately predict traffic-induced noise annoyance levels across different urban areas of Riyadh city.

Key objectives of this study include:

- Developing a robust machine learning algorithm (Support Vector Machine) for predicting noise annoyance levels in Riyadh city.
- Integrating diverse acoustical and non-acoustical datasets encompassing demographic characteristics, traffic conditions, and acoustical factors to enhance prediction accuracy.
- Assessing the performance of the proposed SVM model through a case study focusing on Riyadh, Saudi Arabia.
- Providing insights and recommendations for city planners and policymakers to control and mitigate noise pollution in Saudi Arabia.

Despite the existing body of research on noise pollution and its health impacts, there remains a gap in the utilization of advanced machine learning techniques like SVM for predicting noise annoyance

specifically in rapidly urbanizing contexts such as Riyadh. By addressing these objectives, the present study endeavors to offer a novel approach to managing noise pollution in urban environments, in Riyadh city. Through the amalgamation of machine learning algorithms and traffic noise data, this research aims to foster sustainable urban development practices conducive to the well-being and better satisfaction of life.

MATERIALS AND METHODS

Based on the literature survey, a proposed methodology has been introduced in the study which is presented in Fig. 1. This proposed methodology includes various sections such as study area, socio-acoustics survey, data-preprocessing, support vector machine, and performance matrix.

Study area

Riyadh city, also known as the capital of Saudi Arabia, is characterized by a dynamic urban landscape and an increasing population in the last few years.

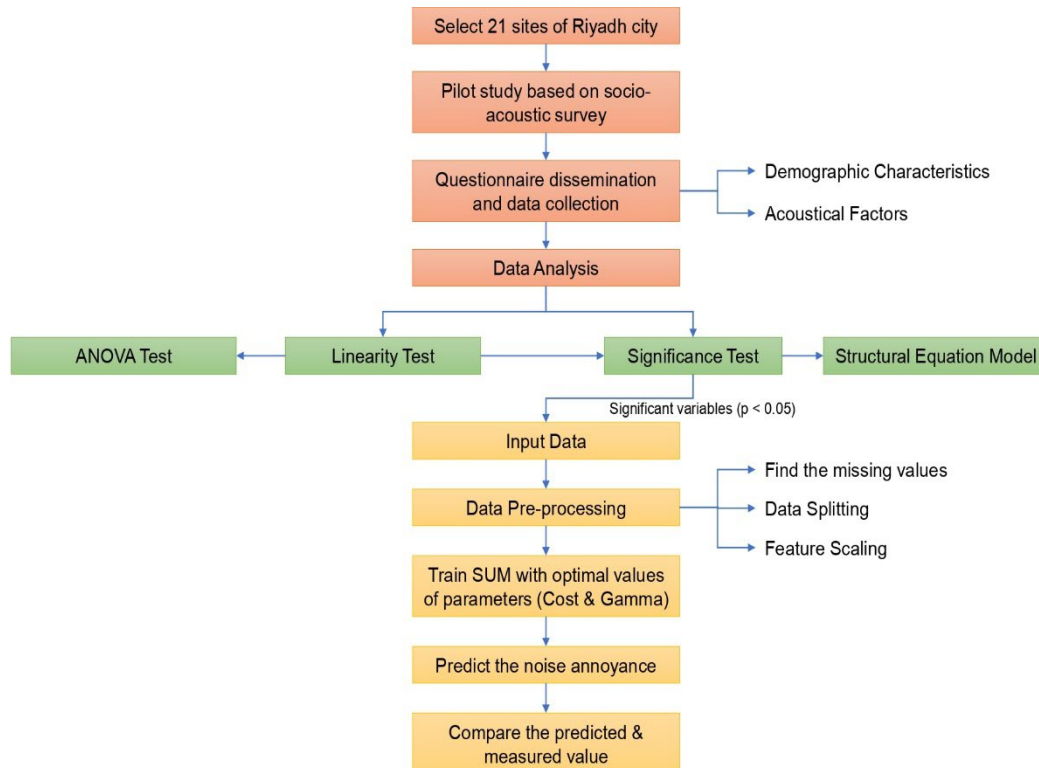


Fig. 1: Research methodology for prediction of noise annoyance

Riyadh city serves as a major economic and cultural hub throughout the Arab region. The traffic scenario in Riyadh is often influenced by the city's expansive road network system, industrial and economic development, increasing population density, and ongoing urban projects (Alghamdi *et al.*, 2021). The city's planning incorporates various locations with diverse metrological characteristics and traffic conditions, mainly from residential and commercial areas. The road characteristics of the city play a crucial role in accommodating the rising number of vehicles, contributing to traffic patterns that vary across different areas. Riyadh's traffic conditions are subject to factors such as population density, land-use planning, and the distribution of residential and commercial zones. The city is situated at a latitude of 24.774265 and a longitude of 46.738586. The study utilized 21 commercial and residential sites in the city has been considered for the study. Table 1 shows the characteristics of various locations such as zoning, latitude, and longitude.

Socio-acoustics Survey

A socio-acoustics survey was conducted in Riyadh city, involving 960 respondents through a random sampling approach at 21 different commercial and residential areas. Householders, shopkeepers, consumers, and working professionals were

considered for the survey. Before the main survey, a pilot study was conducted with 38 participants to validate the reliability of the questionnaire. The survey teams visited selected respondents, explaining the study's purpose and benefits in English and Arabic to ensure understanding. Participation was voluntary, with 928 response sheets obtained. The questionnaire comprised two sections: demographic characteristics and acoustical factors. The demographic characteristics included gender, age, marital status, profession, and education, respectively. Gender and marital status were measured on a binary scale (0 and 1) (Gilani *et al.*, 2021; Das *et al.*, 2021; Nazneen *et al.*, 2020), whereas age and education were measured on a scale of 5 (Das *et al.*, 2021; Tiwari *et al.*, 2023). In the acoustical factors section, traffic flow was rated on a Likert scale of 3, while other factors such as transportation noise, noise sensitivity, and perceived noisiness were rated on a Likert scale of 1 to 5 (Tiwari *et al.*, 2023; Nazneen *et al.*, 2020; Fyhri and Klæboe, 2009).

Data pre-processing

Data pre-processing acts as a critical phase in the predictive modeling of noise annoyance. It consists of three steps i.e., data categorization, data splitting, and feature scaling (Zelaya 2019). The first step in data pre-processing is data categorization

Table 1: Characteristics of various locations of Riyadh city

Locations	Characteristics	Longitude	Latitude
Olaya District	Commercial	46°40'42.27"E	24°41'45.98"N
King Fahd Road	Mix	46°36'53.84"E	24°49'29.05"N
Tahlia Street	Commercial	46°41'26.08"E	24°41'57.65"N
Al-Ma'ather Street	Commercial	46°39'25.80"E	24°43'5.90"N
King Abdulaziz Road	Mix	46°38'29.62"E	24°49'22.73"N
Prince Turki bin Abdulaziz Road	Residential	46°36'44.71"E	24°45'9.56"N
Imam Saud bin Abdulaziz Road	Mix	46°41'24.24"E	24°45'32.45"N
Northern Ring Road	Mix	46°48'16.00"E	24°49'39.71"N
Eastern Ring Road	Mix	46°45'58.36"E	24°42'28.98"N
Southern Ring Road	Mix	46°42'36.70"E	24°35'18.31"N
Makkah Road	Mix	46°32'37.40"E	24°35'26.20"N
Salahuddin Ayyubi Road	Residential	46°45'1.99"E	24°40'15.64"N
King Abdullah Road	Mix	46°43'14.00"E	24°45'5.37"N
Makkah Mukarramah Street	Commercial	46°32'37.13"E	24°35'21.02"N
Thumamah Road	Residential	46°44'3.86"E	24°50'1.51"N
Abu Bakr Al Siddiq Road	Mix	47°18'59.16"E	24° 9'15.49"N
Al-Uraija Al-Gharbiyah Street	Residential	46°36'0.48"E	24°35'23.60"N
Khurais Road	Mix	46°53'10.11"E	24°49'30.72"N
Abu Bakr Al Siddiq Road	Commercial	47°19'0.25"E	24° 9'12.63"N
Al-Qassim Road	Mix	46°45'15.85"E	24°50'30.16"N
Al-Ahsa Street	Commercial	46°43'13.52"E	24°44'9.80"N

of variables which encode the categorical variables (Gender) into numerical format to facilitate their inclusion in the proposed model. This transformation ensures that qualitative information is appropriately integrated into the analysis without introducing bias (Leong *et al.*, 2020). Subsequently, the traffic-induced acoustical and non-acoustical dataset was partitioned into training and testing datasets, adhering to the conventional 80:20 split ratio (Bravo-Moncayo *et al.*, 2019). The data-splitting strategy ensures that the proposed model is trained on a sufficiently large subset of the data while retaining a separate portion for the model evaluation. It is used to prevent variables with larger scales from disproportionately influencing the model training process. The third step in data pre-processing is feature scaling. Min-max scaling was utilized in the present study to transform the features to a comparable scale. Mathematically, Min-Max scaling is represented as (Ambarwari *et al.*, 2020):

$$N_{scaled} = \frac{(N - N_{min})}{(N_{max} - N_{min})} \quad (1)$$

where N_{min} and N_{max} denote the minimum and maximum values of the feature, respectively.

Proposed model-SVM

Support Vector Machine (SVM) is a powerful supervised learning algorithm widely utilized for regression problems (Trafalis and Ince, 2000). For noise annoyance prediction, SVM will prove to be a robust tool due to its ability to handle high-dimensional data and nonlinear relationships. The fundamental principle of SVM is to find the hyperplane that best separates the data points into different classes or, in regression tasks, predicts the continuous target variable with maximum margin (Leong *et al.*, 2020). Mathematically, the hyperplane in SVM is represented as follows (Trafalis and Ince, 2000):

$$w \cdot n + t = 0 \quad (2)$$

where w is the weight vector, n is the input vector, and t is the bias term.

For regression problems, the objective is to find the hyperplane that minimizes the error between the predicted and actual noise annoyance values, which is formulated as follows (Xue *et al.*, 2009):

$$\min_{w,b} \frac{1}{2} \|w\|^2 + c \sum_{i=1}^n (a_i - (w \cdot n_i + b))^2 \quad (3)$$

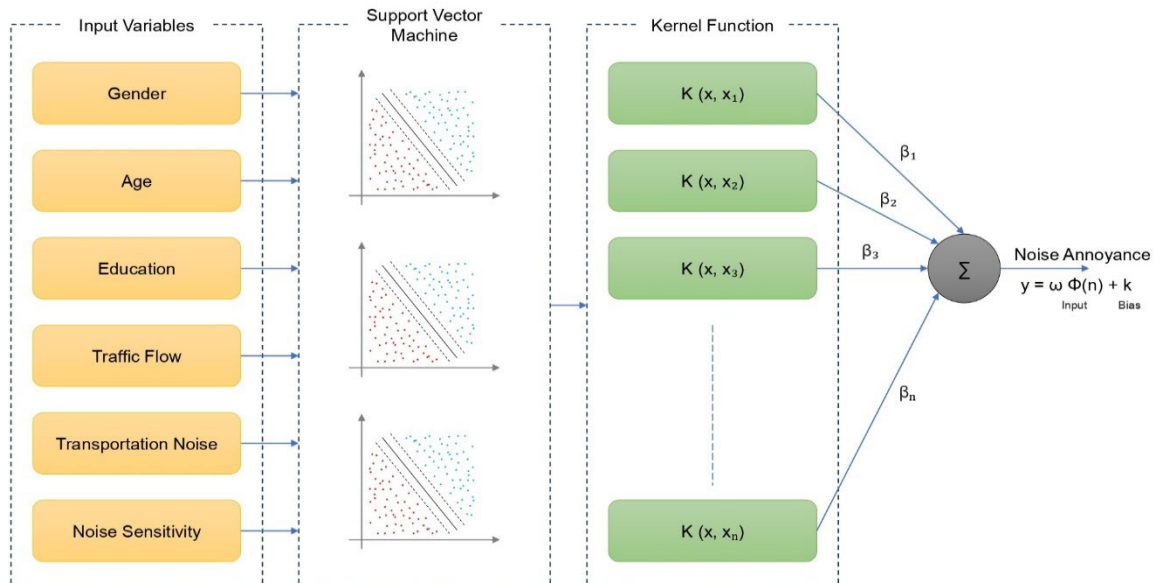


Fig. 2: Architecture of SVM model

Here, C is the regularization parameter that balances the trade-off between maximizing the margin and minimizing the error. SVM employs the kernel function to implicitly map the input data into a higher-dimensional space where the data becomes linearly separable. The most commonly used kernels include linear, polynomial, and radial basis function (RBF) kernels (Tiwari et al., 2022). By optimizing the parameters and selecting the appropriate kernel function, SVM can effectively capture complex patterns in the data and produce accurate predictions for noise annoyance levels. Fig. 2 shows the architecture of the SVM model. It consists of input data, data pre-processing, kernel function, and out variable. In the present study, a radial basis function kernel was employed in SVM due to its flexibility in capturing nonlinear relationships, resulting in a robust predictive model for noise annoyance regression problems (Xue et al., 2009).

Performance matrix

The performance of the SVM model in predicting noise annoyance is assessed using three key metrics: Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and Coefficient of Determination (R^2).

RMSE quantifies the average magnitude of the errors between predicted and actual noise annoyance values, providing insight into the model's overall accuracy. MAE measures the average absolute difference between predicted and actual noise annoyance values, offering a robust evaluation of prediction capability. Additionally, R^2 indicates the proportion of variance in the target variable illustrated by the model, with higher values signifying a better fit. These metrics collectively offer a comprehensive evaluation of the SVM model's performance in noise annoyance prediction. The mathematical formulation for the following performance matrix is given as follows (Tiwari et al., 2022; Patel et al., 2024):

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (a_i - \hat{a}_i)^2} \quad (4)$$

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^n |a_i - \hat{a}_i| \quad (5)$$

$$R^2 = 1 - \frac{\sum_{i=1}^n (a_i - \hat{a}_i)^2}{\sum_{i=1}^n (a_i - \bar{a}_i)^2} \quad (6)$$

a_i , $\hat{a}_i$, and $\bar{a}_i$ represents the actual value, predicted value, and mean of the actual values of the target variable (noise annoyance). n represents the number of samples in the dataset.

RESULTS AND DISCUSSION

Demographic characteristics

Table 2 represents the demographic characteristics of key variables such as gender, age, education, marital status, and profession among the population. Gender distribution indicates a higher presence of males, comprising 89% of the respondents, while females represent 11%. The age variable highlights a range between 18 to above 60, with the majority of respondents falling within the 31-40 age group. The educational variable reveals a significant proportion of individuals with graduation-level qualifications, comprising 48.9% of the respondents, followed by those with a high school (16.5%), master's (13.5%), matric (12.7%), and higher education (8.4%). Marital status indicates a majority of married respondents (86.4%), with a smaller proportion being unmarried (13.6%). Profession distribution shows that a substantial portion of the respondents were self-employed (50.7%), followed by employed respondents (38.7%), and unemployed respondents (10.6%).

Socio-acoustics Survey

Table 3 illustrates the acoustical characteristics of the survey and explores respondent's perception of noise across five key variables: Traffic Flow, Transportation Noise, Noise Sensitivity, Perceived Noisiness, and Noise Annoyance. The respondents reported high traffic flow (45.1%) in the majority of the residential and commercial areas. Transportation noise was found to be a highly prominent factor for traffic-induced noise by 39.2%. Noise sensitivity is structured around the Weinstein Noise Sensitivity Scale (WNSS) (Kishikawa et al., 2006). It consists of 21 questions on a Likert scale of 1 to 5. A substantial proportion reported high (32.9%) or extreme (22.3%) sensitivity to noise. The noisiness perceived by the respondents was reported as high by 31.6% and extremely high by 15.5%. The noise annoyance due to traffic was mostly considered to be moderate (31.7%) and extremely high by 14.3%.

Structural model

Table 4 indicates that the variables show a non-linear relationship, with p-values below 0.05. This analysis confirms that the dataset exhibits non-linear characteristics, making it suitable for input into the SVM model (Memon *et al.*, 2021). The SVM model can extract intricate non-linear features and utilize

them for predicting the targeted noise annoyance variable. Table 5 presents the outcomes from the structural path model, wherein path coefficients gauge the strength and direction of relationships between the constructs. To establish a significant relation between constructs, a path coefficient must exceed 0.2 at a 95% confidence interval (Das *et al.*,

Table 2: Demographic characteristics of the respondents

S.No.	Variables	Level of Measurement	Total Count	Percentage of Count (in %)
1	Gender	Male	826	89.0
		Female	102	11.0
		18-30	228	24.5
2	Age (in years)	31-40	325	35.0
		41-50	181	19.5
		51-60	130	14.0
		>60	64	1.0
3	Education	Matric	118	12.7
		High School	135	16.5
		Graduation	454	48.9
		Masters	144	13.5
4	Marital Status	Higher	77	8.4
		Married	802	86.4
		Unmarried	126	13.6
5	Profession	Unemployed	98	10.6
		Employed	359	38.7
		Self-Employed	471	50.7

Table 3: Acoustical response of the respondents

S.No.	Variables	Level of Measurement	Total Count	Percentage of Count (in %)
1	Traffic Flow	Low	127	13.7
		Medium	382	41.2
		High	419	45.1
		Not at all	21	2.3
2	Transportation Noise	Low	88	9.5
		Medium	256	27.6
		High	364	39.2
		Extreme	199	21.4
3	Noise Sensitivity	Not at all	45	4.8
		Low	127	13.7
		Medium	244	26.3
		High	305	32.9
4	Perceived Noisiness	Extreme	207	22.3
		Not at all	81	8.8
		Low	135	14.5
		Medium	293	29.6
5	Noise Annoyance	High	275	31.6
		Extreme	144	15.5
		Not at all	48	5.2
		Low	182	19.6
		Medium	271	31.7
		High	294	29.2
		Extreme	133	14.3

Table 4: Linearity between the variables

Variables	Df	Sum of Square	Non-Linearity
Gender - Annoyance	1	1.228	Yes
Age - Annoyance	4	2.651	Yes
Education - Annoyance	4	2.905	Yes
Marital Status - Annoyance	1	1.641	Yes
Profession - Annoyance	2	2.544	Yes
Traffic Flow - Annoyance	2	2.218	Yes
Transportation Noise - Annoyance	4	3.936	Yes
Noise Sensitivity - Annoyance	4	2.814	Yes
Perceived Noisiness - Annoyance	4	2.472	Yes

Table 5: Structural model results

Variables	Mean	St.Dev	T-statistics	p-values	Supported
Gender - Annoyance	0.483	0.038	12.716	***	Yes
Age - Annoyance	0.292	0.046	6.358	***	Yes
Education - Annoyance	0.198	0.051	3.892	**	Yes
Marital Status - Annoyance	0.077	0.045	1.714	0.076	No
Profession - Annoyance	0.083	0.072	1.164	0.522	No
Traffic Flow - Annoyance	0.245	0.055	4.465	**	Yes
Transportation Noise - Annoyance	0.674	0.082	8.217	***	Yes
Noise Sensitivity - Annoyance	0.182	0.037	4.936	***	Yes
Perceived Noisiness - Annoyance	0.221	0.042	0.528	0.889	No

Table 6: SVM parametric values

S.No.	Variables	Range	Optimum value
1	Cost	$2^{(-5,5)}$	32
2	Gamma	$2^{(-5,5)}$	32

2022). Table 5 illustrates that all path coefficients were highly significant at a level of 0.001. Evaluation parameters including mean, standard deviation, t-statistics, and p-value were utilized to assess the relationship significance between the constructs. Notably, Gender (t: 12.716), Age (t: 6.358), Education (t: 3.892), Traffic Flow (t: 4.465), Transportation Noise (t: 8.217), and Noise Sensitivity (t: 936) significantly influenced Noise Annoyance. Moreover, Marital Status, Profession, and Perceived Noisiness do not affect Noise Annoyance.

Proposed model

The current study aims to assess the effectiveness of a Support Vector Machine (SVM) model using a multivariate dataset, as outlined in the “Materials and Methods” section, for predicting and conducting

parametric sensitivity analysis of traffic-induced noise annoyance across Riyadh city. A 10-fold cross-validation was employed for each approach with the training dataset, wherein the training set was segmented into 10 subsets for iterative analysis. This cross-validation method was chosen to mitigate the risk of overfitting and facilitate easy parallelization due to the independence of hyper-parameters (Bergmeir *et al.*, 2012). Two hyper-parameters cost and gamma have been taken to architect the SVM model. Table 6 presents parameter values for an SVM model. It includes Cost and Gamma parameters, with ranges from 2^{-5} to 2^5 . The optimum values for both parameters are 32, indicating their effectiveness in the model. These parameters play a crucial role in tuning SVM models for optimal performance. Table 7 illustrates the training and testing prediction

Table 7: Performance matrix of the proposed model

Matrix	Training data (80%)	Testing data (20%)
RMSE	1.162	1.416
MAE	1.307	1.538
R ²	0.93	0.90

Table 8: Sensitivity analysis

S.No.	I/P Variables	Percentage (%)
1	Gender	14.7
2	Age	16.2
3	Education	5.8
4	Traffic Flow	12.9
5	Transportation Noise	21.6
6	Noise Sensitivity	28.8

performance of the proposed SVM model for noise annoyance prediction, obtaining RMSE values of [1.162, 1.416] for the training and testing datasets, respectively. Notably, compared to other machine techniques cited in previous literature (Khorshid *et al.*, 2015, Chand *et al.*, 2016, Tiwari *et al.*, 2022), the Support Vector Machine model demonstrates superior predictive capabilities, because SVM model is less sensitive to outliers and aim for a global optimization solution, aided by their regularization parameter for fine-tuning within the survey dataset acquired from Riyadh city.

Additionally, sensitivity analysis as shown in Table 8 highlights the significance of input variables, such as gender, age, education, traffic flow, transportation noise, and noise sensitivity for their relevance in predicting noise annoyance levels.

Discussions related with hypothesis

Saudi Arabia, as a developing nation, has witnessed a substantial rise in the volume of vehicle density on its roads. However, this rapid expansion of road networks and ongoing infrastructure development, has become a challenge for countries like Saudi Arabia grappling with resource constraints. The sudden boost in vehicular traffic, particularly in industrial or metropolitan cities of Saudi Arabia, has led to a decline in overall quality of life, primarily attributable to heightened levels of traffic-generated noise. Previous research by Tiwari *et al.* (2022) has developed a direct correlation between traffic-

induced noise annoyance levels and increased road traffic, as opposed to air or rail transportation.

A few observations have been acquired from the sensitivity analysis:

- Noise sensitivity is observed to have a sensitivity of 28.8% for noise annoyance. The finding aligns with similar observations by some researchers (Tiwari *et al.*, 2023; Bravo-Moncayo *et al.*, 2019; Park *et al.*, 2017) highlighting noise sensitivity as a primary predictor of noise annoyance. Sensitive respondents tend to experience an adverse effect from traffic-induced noise pollution and more are attuned to environmental stressors (Garg *et al.*, 2022).

- Transportation noise is observed as the second most influencing predictor with a sensitivity of 21.6% of noise annoyance. Nevertheless, researchers such as Sung *et al.* (2017) and Cerletti *et al.*, (2022) have underscored increased transportation noise as a significant contributor to increased noise annoyance. Increased transportation noise is generated due to an increase in traffic flow scenario (Tiwari *et al.*, 2023; Méline *et al.*, 2013; Eze *et al.*, 2018). This is also shown in the sensitivity analysis that traffic flow has a significant effect on noise annoyance (Das *et al.*, 2021; Nazneen *et al.*, 2020).

- Gender, age, and education also emerged as an important variable, with sensitivities of 14.7%, 16.2%, and 5.8% respectively. Multiple studies (Das *et al.*, 2022; Gilani *et al.*, 2021; Tiwari *et al.*, 2023) have attributed to the fact that Gender, age, and education affect noise annoyance.

Limitation and scope for future study

Based on the present study, certain limitation was depicted:

1. The applicability of the SVM model may be limited to Riyadh city, Saudi Arabia, and may not be generalized to other locations of the country due to variations in environmental aspects, metrological factors, urban infrastructure, traffic scenarios, and cultural contexts.
2. The accuracy and reliability of the noise annoyance prediction model heavily rely on the observational labeled data. Limited or inaccurate data on traffic scenarios, demographic characteristics, and other acoustical variables may affect the model's performance.
3. The machine learning model's (Support Vector Machine) complexity may have a deficiency in terms of socio-acoustics data interpretability, scalability, and computational resources required for training the model.
4. Temporal changes, including fluctuations in population density, urban growth, and transportation trends, could impact the model's predictive performance. It's crucial to continuously monitor and adjust the model to accommodate these temporal variations.

Based on the limitation certain future work can be done:

1. Future work will explore the applicability of the deep learning model to predict noise annoyance in other cities within Saudi Arabia considering variations in geographical, cultural, and socio-economic factors.
2. Incorporating real-time data from sensors and IoT devices could enhance the model's accuracy and enable timely interventions to mitigate noise annoyance.
3. Additional variables such as land use patterns, green spaces, and community characteristics to capture a more comprehensive understanding of noise annoyance determinants.
4. Improving the interpretability of the machine learning model could enhance its utility for stakeholders and policymakers.

Policy, practical, and theoretical implication of the study

The findings of this study have significant implications for urban planning and policy-making in Riyadh, Saudi Arabia, and other rapidly urbanizing

cities. The identification of key factors influencing noise annoyance, such as traffic flow, noise sensitivity, and demographic characteristics, highlights the need for targeted noise mitigation strategies (Bröer et al., 2010). Policymakers can leverage these insights to develop and enforce stricter noise regulations, particularly in areas with high traffic volumes and sensitive populations. The implementation of noise barriers, optimized traffic management systems, and designated quiet zones could substantially reduce the impact of traffic-induced noise. Additionally, the study underscores the importance of integrating noise pollution considerations into broader urban development plans to foster sustainable and liveable urban environments. For urban planners and city officials, this study offers practical tools and strategies for mitigating traffic-induced noise annoyance. The developed SVM model, with its high predictive accuracy, can be employed to identify noise hotspots and predict future noise annoyance levels under various traffic scenarios. This predictive capability allows for proactive measures, such as rerouting traffic, adjusting road usage patterns, and planning construction activities during less sensitive times. Moreover, public health officials can utilize these findings to design and implement community awareness programs that educate residents about noise pollution and promote behaviors to minimize noise exposure. The integration of machine learning models into urban planning processes can significantly enhance the effectiveness of noise mitigation efforts. Theoretically, this study contributes to the body of knowledge on environmental noise pollution and its impact on human health and well-being. By employing a two-staged SEM-SVM approach, the research demonstrates the value of combining structural equation modeling with machine learning techniques to analyze complex environmental issues. This methodological innovation provides a robust framework for future studies investigating the multifaceted nature of noise annoyance and other environmental stressors. The study also highlights the importance of considering both acoustical and non-acoustical factors in noise annoyance research, paving the way for more comprehensive and nuanced models in the field of socio-acoustics. Future research can build on this foundation by exploring additional variables and contexts, further

refining the predictive capabilities of machine learning models in environmental health studies.

CONCLUSIONS

The research presents a comprehensive investigation into the prediction of noise annoyance in Riyadh city, Saudi Arabia, utilizing a machine learning framework. The SEM analysis revealed that gender, age, education, traffic flow, transportation noise, and noise sensitivity significantly contribute to noise annoyance. The SVM model, with a RMSE of 1.416 and an R-squared (R^2) value of 0.90, demonstrates strong predictive performance. This underscores its utility in informing urban planning and noise pollution management strategies, highlighting the potential for machine learning models to accurately predict and mitigate environmental stressors. The sensitivity analysis further elucidated the factors contributing to noise annoyance, revealing that noise sensitivity (28.8%) is the most critical factor, followed by transportation noise, age, gender, traffic flow, and education. These findings indicate that individual differences in noise sensitivity must be a central consideration in noise mitigation strategies. Moreover, the significant influence of transportation noise on annoyance levels underscores the necessity for targeted interventions in traffic management and urban design to alleviate noise pollution. The results indicate that older individuals and those with higher education levels tend to report higher noise annoyance, suggesting that demographic factors play a crucial role in how noise is perceived and experienced. Additionally, gender differences in noise annoyance emphasize the need for tailored approaches in addressing noise issues, considering the varying sensitivities among different population segments. The strong performance of the SVM model, with its high predictive accuracy, signifies the model's robustness and reliability in real-world applications. This model can serve as a valuable tool for urban planners and policymakers to identify noise hotspots, predict future annoyance levels, and develop effective noise mitigation measures. By integrating machine learning models into urban planning, cities can proactively manage noise pollution and improve the quality of life for their residents.

AUTHOR CONTRIBUTIONS

M.U. Rehman and M. Kamal compiled the collected data and reviewed the manuscript preparation. S.K. Tiwari performed the literature review, analyzed and interpreted the data, prepared the manuscript.

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CONFLICT OF INTEREST

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

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ABBREVIATIONS (NOMENCLATURE)

C	Regularization Parameter
MAE	Mean Absolute Error
N	Input Vector
R ²	Coefficient of Determination
RBF	Radial Basis Function
RMSE	Root Mean Square Error
SEM	Structural Equation Model
SVM	Support Vector Machine
T	Bias Term
W	Weight
IoT	Internet of Things

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ORIGINAL RESEARCH PAPER

A closer look at the work behavior of Gen Z in Micro, Small, and Medium Enterprises of developing countries

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ABSTRACT

BACKGROUND AND OBJECTIVES: The management of human resources focusing on workplace happiness is gaining significant attention in the study of organizational behavior, particularly in organizations hiring Gen Z. This generation perceives workplace happiness differently, making the factor crucial in understanding work behavior. Therefore, this study aimed to explore the role of workplace happiness as a mediator between motivation and performance among employees in Micro, Small, and Medium Enterprises in developing countries.

METHODS: The study adopted a survey design, obtaining data from 186 young workers across 23 MSMEs in developing countries. Path analysis was also used to test the proposed model.

FINDINGS: The first results in this study showed that motivation significantly affected happiness at work with a p-value of 0.000 below the specified significance level of ≤ 0.005 (5%). The second result also showed that motivation significantly influenced performance with a similar p-value of 0.000. The third result suggested that happiness at work exhibited a significant effect on performance with a p-value threshold. Finally, the study found that happiness at work mediated the relationship between motivation and performance as evidenced by a p-value of 0.000.

CONCLUSION: The study suggested that motivation positively affected happiness at work and further enhanced performance. Additionally, job satisfaction could serve as a mediator between motivation and performance. Cultivating a work environment that prioritizes teamwork, and mutual respect, as well as discourages self-serving behavior could further improve employee happiness, job satisfaction, and overall performance. This improvement would also benefit MSMEs by enhancing work quality

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INTRODUCTION

Firman (2021) reported that during the COVID-19 pandemic, approximately 60 million additional business operators in Micro, Small, and Medium Enterprises (MSMEs) continued operations to ensure survival in the industry. These enterprises significantly contribute to economic growth, accounting for up to 61.07% of the Gross Domestic Product (GDP) in 2021 (Lindo, A. D. C. F., Hermawan, A., & Suharsono, N., 2023). This achievement is due to government support, particularly in terms of financial assistance. For example, a support mechanism is the people's business loans, which as of September 1, 2021, amounted to Indonesian Rupiah (IDR) 177.7 trillion. Besides the loans, various financing models are also available for the 'little people' sector which are facilitated through cooperative financing, the Revolving Fund Management Institution, and funding programs for budding entrepreneurial ventures. MSMEs face significant challenges beyond financial issues to maintain business resilience such as human resource management (Gani, N., Suprayitno, D., Wardhani, D., Al Imran, H., & Rahwana, K.A. (2024), market penetration (Fuadah, I. W., Sulalah, S., Salsabila, N., & Maulana, I. (2024), and cash flow management (Wiardi, A. H., & Saputra, F. E., 2022). Every MSMEs requires equipped managerial and entrepreneurial skills to effectively manage resources and compete in the industry. In the current competitive business landscape where opportunities are scarce and organizational demands necessitate innovative solutions, high-quality human resources are essential. Human resources personnel should be willing to show potential, maximize existing abilities, and even engage in tasks beyond the job descriptions. Happy employees in MSMEs tend to exhibit the highest performance levels (Bangun, Pritasari A, Widjaja FB, Wirawan C, Wisesa A and Ginting H, 2021; Salas-Vallina, A., Pozo-Hidalgo, M. and Gil-Monte, P.R. (2020a); Thompson, A. and Bruk-Lee, V. (2021); and Jaswal, N., Sharma, D., Bhardwaj, B. and Kraus, S. (2024). Despite abundant publications on the relationship between happiness in the workplace and employee performance, studies showing no direct relationship remain limited. Most literature supports a positive correlation between employee happiness and job performance. Certain studies suggest that while employee happiness can enhance specific aspects of performance, it does not necessarily lead

to an overall improvement in employee performance. Therefore, further publications on the impact of happiness at work on employee performance remain crucial. Happiness at work refers to a mindset that enables individuals to maximize work performance and reach their full potential, whether working independently or in groups (Pryce-Jones, 2011). Based on this definition, three principles evolve including (1) happiness at work connects to an individual's mindset and awareness of the job, (2) it occurs both when working independently and collaboratively in groups, and finally (3) happiness at work embodies the concept of a "yin and yang" effect. When an employee experiences happiness at work, the individual tends to exhibit positive behaviors and attitudes that impact both individuals and organizations. Publications on happiness at work have become a focal point for scholars across various fields. Van-Wyk *et al.*, (2020). focused on happiness among day laborers and Bibi *et al.*, (2022) explored this theme in the hospitality industry. Similarly, Meng & Xiao (2022); Dias *et al.*, (2022) investigated happiness at work within the financial sector. Other publications such as Ravina-Ripoll *et al.*, (2022); and Khan & Abbas (2022), investigated happiness at work within the financial sector. Other publications such as Polat *et al.*, (2022) and Minguela-Recover *et al.*, (2022) investigated happiness at work within the financial sector. Other publications such as Miller & Gkonou (2022); and Van-Waeyenberg *et al.*, (2022). Despite extensive studies on happiness at work, few explore happiness experienced by employees in MSMEs sector, particularly among the younger generation. Human resource management issues persist as significant challenges for many MSMEs business owners (Doli, 2022). Effective human resource management which prioritizes principles of human behavior and adopts the Quality of Work Life (QWL) method including fostering employee happiness at work can positively impact performance and influence work behavior within these enterprises. Understanding the behavior of Gen Z which is perceived to have characteristics different from other generations (Francis & Hoefel, 2018; Klopota *et al.*, 2020; Klopota, I., Aleksic, A., and Vinkovic, N., 2020), will help organizations prepare to face Gen Z (Ganguli *et al.*, 2022). This preparation will enable organizations to more easily adapt, engage, and foster intergenerational collaboration

(Benítez-Márquez *et al.*, 2022). Conversely, a study by Lettink showed that the participation of Gen Z in the workforce would significantly increase from 6.4% in 2020 to 33.4% in 2030 (Ganguli *et al.*, Padhy, S. C., & Saxena, T., 2022). Publications on happiness at work including Gen Z are intriguing because some studies report that Gen Z experiences unhappiness in the workplace, while other generations are generally happy at work (Zani, R. M., Ahmad, I. N., & Saad, S. M. (2022). However, another study found no significant difference in happiness at work experienced by Gen Z, Y, and X (Khan *et al.*, Aleem, S., & Walia, T., 2021). Specifically, the influence of work motivation on employee performance is often mediated by happiness at work. Numerous studies suggest that work motivation affects employee performance as evidenced by publications conducted by Al-Aamri *et al.*, (2024); Uz Kurt *et al.*, (2023); Shahzad & Khan (2023); Silva & Rosa (2023); Mishra & Hassen (2023); Kalam *et al.*, (2023); Meng & Hu (2022); scrimpshire *et al.*, (2022); Udin *et al.*, (2023). However, several other studies present findings inconsistent results such as publications conducted by Nilasari *et al.*, (2021); Rosalia *et al.*, (2020); Eliyana *et al.*, (2018). The inconsistency of these results underscores the current importance of publication on employee motivation and performance. According to Work-Life Balance Theory, when employees perceive a balance between work demands and personal needs, the employee tends to feel motivated leading to improved performance. Therefore, exploring how motivation influences performance through happiness at work remains crucial. Observing the gap in previous publications, this study aims to confirm the results by introducing motivation as an antecedent variable of happiness at work and employee performance. The novelty lies in exploring the role of happiness at work as a mediating variable connecting motivation with employee performance. Theoretically, the study contributes to the literature on the relationship between motivation and employee performance mediated by happiness at work. Practically, the results can assist relevant parties such as MSMEs in improving employee performance and maintaining sustainable competitiveness.

Literature review

Work-Life Balance Theory is defined and conceptualized based on two main dimensions:

- 1) *role engagement in various roles in work and non-work life,*
- 2) *minimal conflict between work and non-work roles (Sirgy et al., 2018).*

Thus, an individual perceives work-life balance when their engagement in work and non-work roles is balanced and there is no conflict between them. When an individual feels this balance, it can result in various outcomes such as work-related outcomes (e.g., job satisfaction, organizational commitment, intention to quit, and job performance), non-work-related outcomes (e.g., life satisfaction, family performance, and leisure satisfaction), and stress-related outcomes (e.g., depression, burnout, work-related stress, and family-related stress) (Allen *et al.*, 2000). This means that when an individual has the opportunity to focus on their efforts to create a balance between work demands and personal life for the well-being of both areas, it enhances their motivation to work and strive more effectively, thereby impacting better performance. Motivation is a process that occurs within individuals, wherein they experience the drive, direction, and persistence in their behavior to accomplish specific goals (Robbin & Judge, 2017). Motivated individuals also felt empowered to exert effort towards objective achievement, direct behavior towards the desire, and maintain diligence in their actions to achieve the targets. According to the same source, various factors motivated individuals including

- 1) *Personal factors such as perceived needs, self-confidence, expectations, reinforcement, and objectives.*
- 2) *Job-related factors included salary, advancement opportunities, rewards, supervisors, and coworkers as well as*
- 3) *Organizational factors comprising organizational justice and job design.*

Furthermore, Griffin & Ebert (2015) defined motivation as factors that stimulate individuals to act in specific manners. When employees were motivated, the individuals would engage in behaviors correlated with the desires of those providing motivation. Motivated individuals exhibited specific actions that impacted the evolution of other behaviors such as performance and Organizational Citizenship Behavior (OCB) (Widarko & Anwarodin, 2022; Good *et al.*, 2022), organizational commitment (Norawati *et al.*, 2022; Winda *et al.*, 2022), and job satisfaction (Hajiali

et al., 2022; Akosile & Ekemen, 2022). Although less common, certain studies also positioned motivation as a moderating variable in the relationship between variables, as perceived in publications by Tajpour *et al.*, (2022); Zakiy & Ramadhani (2024); Abdelwahed *et al.*, (2024). Happiness at work was considered a mindset that enabled individuals to optimize work performance and fulfill their potential, whether working independently or in groups (Pryce-Jones, 2011). According to this definition, individuals who experienced happiness at work enjoyed tasks, found pleasure in work, appreciated collaborating with colleagues, felt valued and appreciated, worked efficiently, and understood the objectives and how the targets would be achieved. Consequently, happiness experienced by individuals influenced workplace behavior such as job satisfaction, motivation to progress, and OCB (Negri *et al.*, 2022; Amani-Nezhad *et al.*, 2022; Singh & Banerji, 2022). The antecedents or influencing factors of job happiness included employee engagement and job satisfaction (Kustiawan *et al.*, 2022), attachment style (Momeni *et al.*, 2022), and stress (Cohen-Louck, & Levy, 2022). Performance was commonly used as an indicator of an organization's effectiveness in managing human resources. Individual performance comprises both behaviors and outcomes (Sonnentag, & Frese, 2002). Performance could be interpreted from three perspectives including the following.

- 1) *The individual differences perspective emphasized variations in individual characteristics as sources of performance differences.*
- 2) *The situational perspective focused on situational factors that facilitated or constrained performance.*
- 3) *The performance regulatory perspective, which centers on performance processes.*

Therefore, performance was defined using various methods and considered from multiple aspects. The determinants of performance included factors such as work motivation and organizational culture (Widarko & Anwarodin, 2022), transformational leadership, and social support (López-Cabarcos *et al.*, 2022; Udin, 2023). An individual's performance level could impact workplace behavior within the organization, influencing job satisfaction (Katebi *et al.*, 2022) and work ethics (Rostikawati *et al.*, 2022). Consequently, achieving set performance standards could lead to increased job satisfaction and improved work ethics.

This study aimed to examine the effect of motivation and happiness at work on performance. The role of mediation was also analyzed to determine how happiness at work mediated the effect of motivation on performance. Conducted in mid-2022, the analysis included 23 MSMEs in Bantul, Indonesia. These MSMEs spanned across various industries such as culinary, handicrafts, fashion, and workshop services with a significant portion consisting of enterprises in the culinary sector, particularly cafes. Studies on MSMEs within different industry classifications have attracted interest from scholars in various countries, such as Iran in the international start-up business sector (Tajpour, Hosseini, E., Ratten, V., Bahman-Zangi, B., and Soleymanian, S.M., 2023; Tajpour, M. and Razavi, S.M., 2023), Malaysia in the manufacturing industry (Hossain, Kumar, J., Islam, M.T., and Valeri, M., 2023), Ireland in various industries (O'Reilly Mac An Bhaird, C., Gorman, L., and Brennan, N.M., 2024), New Zealand in the banking industry (Boulanouar, Z., 2024), and Palestine in the food industry (Amer, 2023). However, publications specifically focused on the café business which was a target work sector for Gen Z remained limited.

Hypothesis development

The effect of motivation on happiness at work

Employees who possessed factors that motivated efforts to perform certain behaviors tended to maximize work performance and achieve their potential. When someone desired to work in groups, the employee felt a sense of security at work. Employees experienced value when allowed to express personal desires at work. Respecting others' feelings led to positive emotions, such as happiness and pride while working. Therefore, motivation at work further influences happiness at work. Several studies supported this discovery, showing that work motivation impacted happiness at work (Amani-Nezhad *et al.*, 2022; Atan *et al.*, 2021; Junça-Silva & Menino, 2022; Maria *et al.*, 2022; Wongsupaluk, 2021; Yap *et al.*, 2022). The first hypothesis proposed is

H1: Motivation influences happiness at work.

Effect of motivation on performance

In a work setting, employees who perceived factors directing behavior acted in a certain manner and showed high intensity tended to achieve desired work outcomes. Employees were more inclined

to establish good and effective relationships with colleagues, supervisors, and others when proper attention was placed on the feelings of others at work. Employees who openly expressed disagreement with others often experienced trustworthiness. Those with high motivation in work were more inclined to achieve high-performance levels. This was supported by several previous studies that showed the influence of motivation on performance (Affuso *et al.*, 2022; Alie *et al.*, 2022; Good *et al.*, 2022; Haq *et al.*, 2022; Hidayati, & Zulher, 2022; Norawati *et al.*, 2022; Yoon, 2022; Roussillon-Soyer *et al.*, 2022; Zubaidah, R.A., Haryono, S. and Udin, U., 2021. Therefore, the second hypothesis of this research is

H2: Motivation influences performance.

Effect of happiness at work on performance

The job satisfaction experienced by employees while working within an organization motivated positive behavior and a focus on performing well. When an employee consistently managed work activities, tasks were efficiently completed within given deadlines and adapted to unforeseen changes in job demands to meet schedules. Employees understood assigned tasks and responsibilities, set priorities, and created work plans using appropriate procedures, tools, equipment, and materials when work expectations were fulfilled. Therefore, happiness at work impacted employee performance. This idea was supported by several studies that consistently showed happiness at work affecting employee performance (Alahbabi *et al.*, 2021; Bangun *et al.*, 2021; Lester *et al.*, 2022; Meng & Muthuveloo, 2022;

Mauri *et al.*, 2021; Arar & Öneren, 2021; Vieira, 2022; Zapata-Lamana *et al.*, 2021). Therefore, the third hypothesis proposed is

H3: Happiness at work affects performance.

From the discussion, the study concluded that when employees were driven by factors motivating behavior, work performance and desired objectives were achieved leading to positive work behavior and outcomes. When employees preferred working in groups over working alone, the employees were better equipped to overcome challenges at work and complete tasks within deadlines. Therefore, work motivation stimulated the evolution of job happiness and further enhanced employee performance. Based on this discovery, the fourth hypothesis proposed was observed as follows.

H4: Motivation influences performance mediated by happiness at work.

Based on the four hypotheses derived, the proposed study model is depicted in Fig. 1.

MATERIALS AND METHODS

Research methods and design

This study aimed to investigate the mediating role of happiness at work in the relationship between motivation and performance among employees of MSMEs in developing countries. A quantitative descriptive method was adopted which was highly useful in studying human behavior. This method further provided a systematic and measurable medium to collect, analyze, and interpret data, eventually helping to better understand and predict human behavior. The study focused on MSMEs in Bantul,

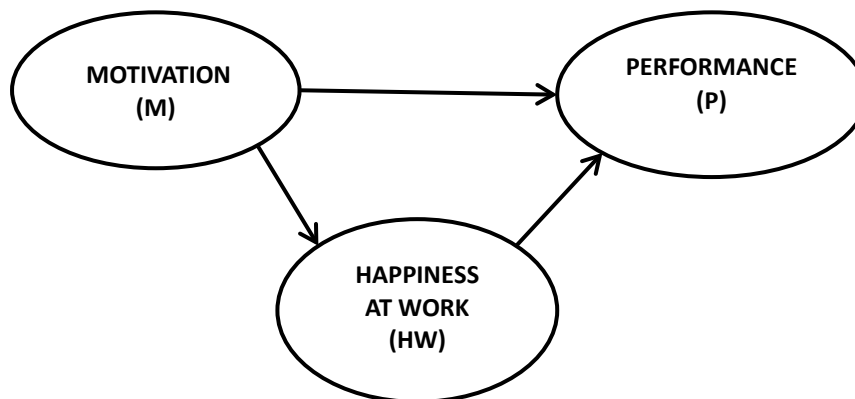


Fig. 1: Research model

Indonesia with the subjects being the employees in the Bantul Regency area. The selected MSMEs were those operating in the culinary industry, specifically cafes. The enterprises further gained popularity since COVID-19 and hired a minimum of 10 employees, suggesting the SMEs were relatively large and professional. The data used in this study were primary, specifically regarding Work Motivation, Happiness at Work, and Performance along with personal data. The data collection method included a survey method through the offline distribution of questionnaires. Each targeted café experienced an initial observation to ensure it met the criteria for selected MSMEs. Subsequently, direct communication was established with the café owner or manager to obtain permission for the study and offline distribution. The timing of the questionnaire distribution was adjusted according to the café's conditions and was coordinated with the café owner/manager which led to a response rate of 95%. The variables used in this study included Work Motivation, Happiness at Work, and Performance. To measure Work Motivation, a portion of the construct from Steers & Braunstein (1976) consisting of five questionnaire items was incorporated. For the happiness at work variable, a questionnaire adopted from Lutterbie & Pryce-Jones (2013) comprising 25 questionnaire items was used, and a measurement tool from Mathis and Jackson in Chishti, et al., (2010) was adopted for the Performance variable. All three instruments underwent validity and reliability testing, confirming that all question items were valid and the three instruments had a Cronbach's alpha greater than 0.7. To test the four hypotheses, Path Analysis was adopted using steps that included Simple Linear Regression Analysis and Multiple Regression (Alni et al., 2018).

RESULTS AND DISCUSSION

Result

The study was conducted in mid-2022 including 23 MSMEs in Bantul, Indonesia. These MSMEs were

spread across various industries such as culinary, crafts, fashion, and workshop services with a predominantly focus on MSMEs operating in the culinary sector, particularly cafes. Questionnaires were distributed both in hard copy and electronically via Google Forms, either directly to MSMEs employees or through local managers or designated personnel. The data analysis from 186 respondents showed that the majority were male (67% or 124 individuals), aged between 20 and 40 years (94.5% or 173) with a high school education level (70% or 129 individuals). Most had work experience of less than one year (43% or 79 individuals) or between one to five years (52% or 96 individuals). These demographics characterized the respondents as young MSMEs employees with relatively good education and work experience. This demographic composition correlated with the industries examined in the study, particularly the culinary (café) and fashion sectors which primarily catered to young consumers. Consequently, there was a need for young workers to deliver services that met the preferences of the target audience.

Before testing the hypotheses, the study conducted a questionnaire examination including a validity test to assess the validity of the question items used in the instrument for measuring the variables. A reliability test was also conducted to ensure consistent results from using the questionnaires when measuring the same respondent at different times. The validity test showed that the 25 questions related to happiness at work variable and the five questions related to motivational and performance variables were valid. In Table 1, the results from the reliability test showed that Cronbach's alpha value for all three variables exceeded 0.6, suggesting good reliability. Descriptive analysis (mean) was conducted for each question item of the variables and the mean of the variables. Results from the descriptive analysis, as depicted in (Table 2), showed that all question items related to happiness at work variable scored above 4 with an average variable value of 4.1, signifying

Table 1: Validity and reliability test

Variable	P value	Cronbach Alpha
1. Motivation	0,00*	0,630
2. Happiness at work	0,00*	0,931
3. Performance	0,00*	0,743

* Correlation is significant at the 0,01 - 0.05 level (2-tailed).

high levels of happiness. This was reported by all 186 respondents across all aspects of the work division. Regarding motivational variables, all question items ranged from 3.6 to 4.2 with an average variable value of 3.9. These variables showed high levels of motivation reported by all 186 respondents across all aspects of work division, though not as high as perceived job happiness. For performance variables, all 186 respondents reported good performance with an average score of 4.2. This high performance was evident across all aspects of performance with values ranging from 4.1 to 4.2. Based on the descriptive analysis, the study concluded that employees from the 23 MSMEs expressed high job satisfaction, motivation, and performance. Despite coming from different industries including culinary, fashion, crafts, and workshop services, all respondents reported positive behavior in the respective workplaces.

This study adopted the path analysis method which was used to test whether happiness at work variable acted as a mediating variable in the relationship between motivation and performance of MSMEs employees. Before conducting various testing steps, the results of the Common Method Variance (CMV) test were presented. The testing results showed that among the 35 items in Motivation, happiness at work, and performance variables, the percentage of variance suggested was 26.964% lower than 50%. This implied that there was no common method bias, prompting the data to be used for further analysis. In this first step, analysis was carried

out using simple linear regression to test the effect of motivation on happiness at work (H1). The results of the simple regression analysis as depicted in Table 3 showed that the significance level was 0.00 lower than the required limit of 0.05. Therefore, the study concluded that H1 was accepted, implying that there was an influence of motivation on happiness at work. Table 2 also showed a positive Beta value of 0.580, implying that higher motivation led to greater job satisfaction experienced by 23 MSMEs employees. The effect of motivation on happiness at work was relatively strong (beta coefficient 0.580). The motivation variable made a significant contribution to changes in employee happiness, namely 33.3% (adjusted R square).

In this second step, analysis was conducted using multiple linear regression to test the effect of motivation and happiness at work on performance (H2 and H3). The results of the multiple regression analysis can be seen in Table 2. Table 3 shows that the significance level is 0.00 which means it is lower than the required limit of 0.05. So, it can be concluded that hypotheses 2 and 3 are accepted, meaning that there is an influence of motivation and happiness at work on employee performance. Table 2 also showed that the Beta coefficient value for the motivation variable was 0.283, suggesting higher motivation leading to better performance produced by employees in the 23 MSMEs. The effect of motivation on performance was relatively strong with a Beta coefficient of 0.283. The third step included comparing the direct and

Table 2: Descriptive statistic of research variable

Variable	Mean	SD
1. Motivation	4,1	0,866
2. Happiness at work	3,9	0,756
3. Performance	4,2	0,721

Table 3: Hypotheses testing result

Hypothesis	Code	Coefficient	T-value	P-Value	Conclusion
Direct effect					
M → HW	H1	0,440	7,86	0,000	Significant
HW → P	H2	0,581	11,381	0,000	Significant
M → P	H3	0.182	3,359	0,000	Significant
Indirect Effect					
M → HW → P	H4	0,256	3,999	0,000	Significant

M: work motivation; HW: Happiness of Work; P: Performance

indirect effects to determine whether the variable of job happiness acted as a mediating variable in the relationship between work motivation and performance (H4). The Sobel test was used to assess the mediating effect in the relationship between the independent and the dependent variables. In this study, the Sobel test was carried out using an online Sobel test application. The Sobel test statistic obtained from the effect of motivation on happiness at work and the impact of happiness at work on performance was 3.127 with a significant two-tailed probability of 0.00. This suggested that the variable of happiness at work could act as a mediating variable, signifying an influence of work motivation on employee performance mediated by happiness at work. Based on these results, the study concluded that H4 was accepted.

1) Motivation has a significant positive influence on happiness at work: The study showed that motivation significantly and positively influenced happiness at work. The results correlated with established theories and previous publications which emphasized the critical role motivation played in enhancing happiness at work (Amani-Nezhad *et al.*, 2022; Atan *et al.*, 2021; Junça-Silva & Menino, 2022; Maria *et al.*, 2022; Wongsupaluk, 2021; Yap *et al.*, 2022). Motivation as an internal factor strongly influences how individuals perceive and experience work (Farooq *et al.*, 2024). Highly motivated individuals tended to feel more satisfied with work, experiencing greater levels of happiness compared to those with lower motivation (Toshniwal & Narendran 2020; Jaw *et al.*, 2016). These results underscored the importance for companies and organizations to focus on motivational factors as a strategy to enhance employee happiness. In practical terms, the results of this study carried significant implications for managers and organizational leaders. By recognizing the importance of motivation in influencing happiness at work, managers could design interventions and programs aimed at improving employee motivation. Implementing effective training, career development, and incentive programs could also serve as tools to motivate employees, eventually increasing happiness at work. Additionally, the study opened avenues for further exploration into other factors that might interact with motivation in shaping happiness at work. Future publications could explore how elements such as workload, leadership style, and

organizational culture might moderate or mediate the relationship between motivation and happiness at work. This study not only provided insight into the direct connection between motivation and happiness at work but also led to a deeper understanding of the dynamics influencing individual work experiences.

2) Motivation has a significant positive influence on performance: The study showed that motivation had a significant positive impact on performance. This discovery was consistent with theoretical perspectives and previous publications that outlined the importance of motivation in enhancing performance (Affuso *et al.*, 2022; Alie *et al.*, 2022; Good *et al.*, 2022; Haq *et al.*, 2022; Hidayati, & Zulher, 2022; Norawati *et al.*, 2022; Yoon, 2022; Roussillon-Soyer *et al.*, 2022; Zubaidah *et al.*, 2021). Motivation as the internal drive that propels individuals toward achieving specific objectives, plays a crucial role in determining job satisfaction and the energy levels required to complete tasks (Al-Aamri *et al.*, 2024). This motivation stimulated employees to work harder, more efficiently, and effectively, which eventually improved performance (Uzkurt *et al.*, 2023). These employees played a crucial role in determining job satisfaction and the energy levels required to complete tasks (Silva & Rosa 2023). High motivation fostered a positive work environment where employees supported each other and collaborated to achieve common objectives (Hidayati, & Zulher, 2022). Intrinsic motivations such as a sense of achievement, recognition, and self-development provided deeper job satisfaction compared to extrinsic counterparts including financial incentives. Employees tended to be more passionate and dedicated at work when the job was perceived to be meaningful and facilitated positive contributions (Haq *et al.*, 2022). This led to improved individual performance and overall productivity of the organization. Additionally, motivation significantly enhanced employee engagement. Motivated employees were more inclined to be engaged in work, taking initiative and actively contributing to decision-making processes. This high level of engagement often led to innovative ideas and creative solutions that improved the organization's overall performance. The results also emphasized the importance for organizational managers and leaders to prioritize happiness at work by creating a pleasant environment and offering opportunities for employee career development.

Furthermore, management needed to adopt strategies that enhanced employee engagement, such as recognizing achievements, offering incentives, and fostering effective communication. The study also uncovered possibilities for future publications to explore specific factors influencing happiness at work and the contributions to performance. Future publications could also examine the differential effects of happiness at work on performance across various industries or cultural contexts to determine the universality of these results or any significant contextual variations.

3) *Happiness at work has a significant positive effect on performance:* The study found that happiness at work had a significant positive effect on performance. The results were consistent with theories and previous publications that stressed the importance of happiness at work in enhancing performance (Alahbabi *et al.*, 2021; Bangun *et al.*, 2021; Lester *et al.*, 2022; Meng & Muthuveloo, 2022; Mauri *et al.*, 2021; Arar & Öneren, 2021; Vieira, 2022; Zapata-Lamana *et al.*, 2021). This showed that higher levels of happiness at work led to better performance of employees in carrying out tasks. Employees who felt happiness at work tended to perform at higher levels than those who were less satisfied (Wittayapornpipat & Wongaud 2023). Happiness at work increased employees' intrinsic motivation, which positively impacted performance (Hermania *et al.*, 2023). Additionally, work engagement theory emphasized that higher engagement at work often influenced by happiness was directly related to improved performance (Lester *et al.*, 2022). The results carried significant implications for management and policymakers in organizations. By enhancing job happiness through appropriate interventions such as rewarding employee achievements and providing compensation, overall employee performance could be improved. The results of this study also suggested opportunities for further publications into the specific factors contributing to happiness at work and the influence on various dimensions of performance. Future publications could investigate moderating or mediating variables that might affect the relationship between rewards and happiness, as well as explore variations in these effects across different industries or organizational contexts.

4) *Motivation affects performance mediated by happiness at work:* The study showed that motivation

impacted performance through the mediating effect of happiness at work. Motivation which was often associated with improved employee performance (Good *et al.*, 2022; Haq *et al.*, 2022), generally led employees to work harder, stay focused, and operate more efficiently to increase productivity and overall performance (Hidayati, & Zulher, 2022). However, the direct relationship between motivation and performance was not simple and linear (Roussillon-Soyer *et al.*, 2022). Various factors could influence or strengthen this relationship with happiness at work being part of the most significant indicators of employee well-being (Alahbabi *et al.*, 2021). Happiness at work is often considered one of the important indicators of employee well-being (Zapata-Lamana *et al.*, 2021). Happiness at work was not only related to positive moods or emotions but also included feelings of satisfaction, motivation, and commitment to work (Lester *et al.*, 2022). Happiness at work influences various aspects of professional life including productivity, creativity, and loyalty (Vieira, 2022). Employees who experienced happiness at work tended to perform better, engage more in tasks, and exhibit less burnout (Arar & Öneren, 2021). Although highly motivated employees generally performed better than those with low motivation (Affuso *et al.*, 2022). Further analysis showed that happiness at work played an important mediating role in this relationship. High motivation increased happiness at work which further stimulated employee performance. In other words, happiness at work strengthens the relationship between motivation and performance. This implied that motivated and happy employees were more inclined to achieve optimal performance.

The results had practical implications for organizations as only increasing the motivation of employees was insufficient to enhance performance. Management also needed to cultivate a work environment that supported employee happiness. This could be achieved through various mediums such as providing comfortable facilities, fostering a positive work culture, offering appropriate rewards and recognition, as well as ensuring a balance between employees' work and personal lives. Therefore, organizations could maximize employee potential and achieve better results

Limitation and recommendations

Based on the results of the study, future

publications could modify the model to include other factors that might influence performance. This modification was necessary since numerous factors beyond motivation and happiness at work could affect performance. The study further showed that motivation and happiness at work contributed only 33.3% to performance, suggesting the presence of other influential factors future publications could explore. Potential factors to consider in modifying the study model included workload (Bartram et al., 2023), leadership style (Pizzolitto et al., 2023), compensation (Almarayeh, 2023), organizational culture (Stasa & Macheck, 2024), and reward (Spitzer et al., 2024). Additionally, business practitioners could use the results of this study to assess and measure whether motivation and happiness at work were sufficient within the organizations. This assessment would be valuable for conducting early scans to detect performance issues. Effective early detection would allow organizations to take preventive measures before performance deteriorates, ensuring that employee performance remains at an optimal level.

CONCLUSION

The study concluded that motivation had a positive impact on happiness at work and positively influenced performance. Happiness at work also appeared to mediate the relationship between motivation and performance. Therefore, developing a workplace environment that emphasizes teamwork, mutual consideration, and discouraging self-serving behavior could enhance employee happiness, job satisfaction, and performance. These improvements would eventually benefit MSMEs by raising work quality and productivity. The study further introduced a novel method by exploring the relationship between happiness at work, motivation, and employee performance in developing countries, particularly within MSMEs. Publications on employee behavior in MSMEs remained limited, often focusing on organizational performance or the perspectives of the owners. A unique aspect of this study lay in the respondents, where the majority were young individuals with diverse perceptions of workplace behavior.

AUTHOR CONTRIBUTIONS

Astuty was responsible for analyzing and interpreting the research results and for drafting the

manuscript. The literature review was drafted by R.J. Astuti. S. M. Mahmud and Veri Widodo managed the distribution of the questionnaire to the respondents.

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CONFLICT OF INTEREST

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

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Tehran Urban Research & Planning Centre (TURPC) takes a neutral position about claims on disputed territories, place names, international boundaries, jurisdiction in published maps, and institutional affiliations. TURPC is committed to retracting a paper after its publication if it becomes apparent that there are serious problems in its content, in terms of research and publication ethics (<https://www.ijhcum.net/journal/process?ethics>).

ABBREVIATIONS (NOMENCLATURE)

CMV	Common Method Variance
IDR	Indonesian Rupiah
GDP	Gross Domestic Product
MSMEs	Micro, Small, And Medium Enterprises
OCB	Organizational Citizenship Behavior
QWL	Quality of Work-Life

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ORIGINAL RESEARCH PAPER

Exploring the dynamics of human resources apology in organizational communication

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ABSTRACT

BACKGROUND AND OBJECTIVES: The emotional expression of feelings and the satisfaction of social needs are two primary purposes of many communication interactions in an organization. As a universal aspect of human interaction, the apology has sparked great interest in its study across a wide range of disciplines. However, the human resources apology has not been involved integrally in the context of organizational communication. Therefore, the research question is, what are the dynamics of human resources apology in organizational communication in Iran?

METHODS: This was a qualitative study conducted using grounded theory. The research was conducted, and sampling was theoretical in municipalities in Iran. For data collection, semi-structured in-depth interviews with the 5W1H technique were conducted with 13 managers, who respond to citizens' requests in the central building of municipalities in Iranian provinces. The researched community comprises human resource managers with at least five years of beneficial work experience in the municipality and relevant knowledge of apology. Targeted sampling has been done based on the researcher's considerations.

FINDINGS: The analysis of the interviews resulted in a set of fundamental topics collected during the open coding process. Sixteen categories were extracted from these fundamental topics. Then, in the axial coding stage, the link between these categories was determined under the following headings causal conditions, core category, contextual conditions, intervening conditions, strategies, and consequences of human resources apology in the form of an axial coding paradigm. In the present study, data analysis was performed using ATLAS.ti software version 8 in three stages of primary, central, and selective coding, which resulted in the identification of 5 categories, 15 central concepts, and 126 final codes.

CONCLUSION: The developed process model provides a comprehensive understanding of the human resources apology process in municipalities in Iran. The study highlights the importance of conflict management, individual behavior, motivation, audience strength, acceptability, apology graph, apology method, audience identity, communication quality, patience, and incompatibility in the human resources apology process.

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INTRODUCTION

In today's modern world, municipalities rely heavily on human resources to coordinate and manage their activities, and interpersonal communications are seen as an essential component of Human relationships (Velmurugan, 2016). In this setting, professional connections and interpersonal dynamics can have a significant impact on the efficiency and effectiveness of public service delivery. Understanding the nuances of workplace relationships within a municipal organization can provide valuable insights for improving organizational culture, fostering collaboration, and enhancing the overall quality of local government operations (Tajpour et al., 2022). A person spends most of his day in the organization and cannot work alone (Lee and Tao, 2020). Communication is an unavoidable objective reality in municipalities, and it has recently been recognized as a necessary condition for productive job performance within municipalities (Agba, 2018). Business communications, in other words, are interpersonal and particular communications that have significant effects on individuals within municipalities (Nwinyokpugi and Omunakwe, 2019). As with any activity, they may result in conflicts that need to be resolved for mutual communications to continue (Myers and Myers, 1988). At best, conflict is disruptive; at worst, it is incredibly destructive. However, conflict can also have significant benefits, when handled skillfully, it can foster intimacy, stimulate technical progress, and help social organizations emerge and renew (Fehr and Gelfand, 2010; Kilag et al., 2024). The apology is one of the inclusive components of human interactions (Shafa et al., 2017), and it is the most practical skill wrongdoers can employ to promote reconciliation with the victim (Utikal and Fischbacher, 2013). It has become a robust and all-encompassing solution for interpersonal communications. If designed carefully, it can be both efficient and cost-effective (Fang, 2019). Apologies are made for various reasons, including those related to the wrongdoer, the victim, or others. However, they all stem from the belief that saying and accepting an apology can accomplish something (Benoit, 2024). Apologies help to repair numerous communications and restore coordination in interpersonal communications (Scher and Darley, 1997). Additionally, an apology increases the victim's willingness to forgive and decreases anger and hostility toward the wrongdoer (Exline

et al., 2007). It resolves the conflicts and restores communication after the damage to the previous state (McCullough et al., 1997). Unresolved conflict with coworkers in the workplace is linked to a decrease in organizational commitment, an increase in the intention to leave, and poor performance at work (Morrison, 2008). Apologies can be used to resolve these conflicts, improve customer experiences, and increase leader effectiveness (Liao, 2007). Fundamentally, an apology seeks to make the wrongdoer morally accountable, and one of its curative effects is to restore moral balance. It is anticipated that victims will recover more quickly from the emotional and psychological effects of violations when violators make amends and mend broken communications (Cheung et al., 2019) so that leaders can resolve conflicts with their messages and win the respect and satisfaction of their workforce (Minei, 2022). Several definitions for the phenomenon of apologizing have been put forth over the past few years, but none of them have ultimately found universal acceptance (Smith, 2008). The following are the elements that all definitions have in common: 1) A clear statement that prefaces the apology, 2) expressing regret or sadness, 3) Identification of the transgression, 4) Acknowledgment of responsibility for the transgression, 5) An explanation for the cause of this transgression, 6) Commitment to non-repetition, and 7) offer to compensation 8) request for forgiveness (Bippus and Young, 2020). Research suggests that apology is one of the most profound human interactions (Lazare, 2005). Although all the theories and definitions put forth have been derived from scientific thinking and debate, and there may be some shared aspects among them, ultimately, there are many ambiguities in this regard (Allan et al., 2015). Empirical research supports the notion that apologies are not always effective (Skarlicki et al., 2004), prompting the question of why some apologies succeed while others fall on deaf ears (Fehr et al., 2010). Despite the incidence of apologies, claims of their effectiveness, and implicit theories about when they are effective, quantitative studies have been conducted on how this phenomenon works (Wooten, 2009).

The background review in this area, such as (Robertson et al., 2023), shows that most studies have only focused on examining the relationship between "one or two predetermined factors by the

researcher” and the “apology phenomenon,” and these factors have been selected in a scattered, partial, and diverse manner. Moreover, selecting factors from the beginning has prevented the emergence of hidden factors during the research process. As a result, the way this phenomenon works as a process from beginning to end in all dimensions has not been explained transparently. To the extent that the lack of a comprehensive theory of apologies has become one of the notable features of psychological literature (Imada *et al.*, 2023). Municipalities are dealing with working conditions full of nervous and psychological pressure, high workload, physical injuries, and non-standard working environments in addition to economic problems affected by the recession (Rajabipoor Meybodi *et al.*, 2024). Therefore, these conditions, while lowering the tolerance threshold of employees, lead to various conflicts in the organization. Consequently, an apology is effective in controlling and reducing these conflicts (Hosseini *et al.*, 2020). The apology can help restore trust and improve relationships between municipalities and their citizens (Gkinopoulos, 2022). When municipalities make mistakes or cause harm, a sincere apology can go a long way in acknowledging the wrongdoing, taking responsibility, and showing a commitment to do better. This can help rebuild the public’s faith in local government (Enwereji and Uwizeyimana, 2020). Municipalities that cultivate a culture of apology and accountability tend to have a stronger ethical environment overall. Apology requires honesty, humility, and a commitment to improvement - qualities that are central to good governance and ethics. Therefore, this study has created a comprehensive and integrated theoretical framework for this phenomenon by discovering new concepts and practical factors, defining new relationships in all dimensions of this phenomenon, as well as strengthening effective factors and previous relationships, thereby covering shortcomings, enriching, and organizing the literature on apologies. To develop a model of apology, the goal of this study is to know and understand people’s experiences and interpretations in the area of apology. The current study has been carried out in Iran in 2024.

Theoretical foundations

Human resources apology

Apologies are a critical component of conflict

resolution and relationship-building within organizations, and human resources professionals play a pivotal role in facilitating and guiding this process (Thompson, 2019). Workplace conflicts can often be resolved through sincere apologies, which can help rebuild trust, restore damaged relationships, and prevent escalation. Human resources professionals can help identify situations where an apology is warranted and guide the parties involved in delivering it effectively (Fehr and Gelfand, 2010). When misconduct or unacceptable behavior occurs, human resources can ensure that the responsible party takes ownership of their actions and delivers a meaningful apology (Wang *et al.*, 2023). This involves helping the wrongdoer understand the impact of their behavior and the importance of acknowledging it. Human resources can provide coaching and support to help the person apologizing craft a sincere, specific, and actionable apology (Battistella, 2014). This may include advising on the appropriate tone, timing, and format of the apology, as well as facilitating face-to-face or written communication. By managing workplace apologies effectively, human resources can contribute to the development of an organizational culture where employees take responsibility for their actions and are willing to engage in restorative practices (Seiter *et al.*, 2023). This can enhance trust, collaboration, and overall employee well-being (Risen and Gilovich, 2007). In some cases, human resources may need to navigate the legal implications of apologies, as they can be perceived as an admission of guilt or liability (Zammit Young, 2023). Human resources professionals should seek legal counsel to ensure that apologies are handled in a manner that protects the organization’s interests while still addressing the underlying issues (Nosrati-rad, 2023). Human resources can play a role in monitoring the effectiveness of apologies and the subsequent healing process. This may involve follow-up conversations, mediation, or other interventions to ensure that the apology has been accepted and the relationship has been repaired. Apologies as a transactional act between two individuals is evolving towards a more expansive perspective. The act of apologizing, previously seen as an interpersonal action, is now being interpreted more broadly. Individuals may perceive the verbal act of apologizing as aversive, even when they acknowledge their responsibility to engage in cooperative behavior. In

such cases, nonverbal behavior may be considered a form of politeness strategy, particularly when there is no face-threatening action (Chavez *et al.*, 2024). Employees accept this embracement of collective guilt and shame, not only in an abstract sense but also to the degree that they participate in organized contrition rituals where they apologize and ask for forgiveness on behalf of the organization (Frandsen *et al.*, 2024). By understanding the complexities and best practices surrounding workplace apologies, human resources professionals can contribute to developing a more positive, collaborative, and accountable organizational culture. This, in turn, can lead to improved employee engagement, reduced conflict, and enhanced organizational performance.

Organizational communication

Organizational communication is a critical component of any successful organization, as it encompasses the channels, processes, and dynamics through which information is exchanged, relationships are built, and collective goals are achieved. This field of study provides valuable insights into how communication shapes the internal workings and external interactions of organizations. At its core, organizational communication involves the transmission of messages, both formal and informal, among individuals and groups within an organization (Mifune *et al.*, 2019). This includes communication between managers and employees, cross-departmental collaboration, and the organization's outreach to external stakeholders such as customers, partners, and the broader community (Qin and Men, 2023). Clear and coordinated communication enables employees to understand their roles, responsibilities, and the steps required to complete tasks and achieve organizational objectives. Open and transparent communication helps organizations navigate changes, whether technological, structural, or strategic, by keeping employees informed and engaged. Interpersonal communication fosters trust, collaboration, and a sense of shared purpose among organizational members, which is essential for morale and productivity. Formal communication channels, such as policies, procedures, and reporting structures, help organizations coordinate their activities and maintain control over operations (Bentley, 2018). An organization's communication with external stakeholders, through marketing, public relations,

and other outreach efforts, shapes its public image and reputation. Organizational communication is a dynamic and evolving field, as the communication landscape continues to be transformed by technological advancements and shifting societal expectations (Emeka-Okoli *et al.*, 2024). Scholars and practitioners in this domain explore topics such as the impact of remote work on internal communication, the role of social media in external communication, and the importance of inclusive and culturally sensitive communication practices (Hosseini and Rajabipour Meybodi, 2023). By understanding the complexities and nuances of organizational communication, leaders and employees can work to enhance the flow of information, strengthen interpersonal connections, and ultimately, drive the success and sustainability of their organizations (Arabiun *et al.*, 2024). When an organization is seen to have put an object at risk, such an organization engages in discourse and communication as a way to socially construct its reputation and/or repair its image and shape the epistemology of risk. Image and reputation management communication should only happen after addressing public safety, especially in safety-critical situations. Risk receptors must know how to safeguard themselves based on factual incident information before the organization considers reputational concerns (Ambituuni *et al.*, 2024). Organizational communication design logic is a model of relationships that connect specific communication choices and organizational expectations for what communication choices will produce. Providing more holistic accounts of communication choices may make it easier to make the case for sharing communication designs (Barbour *et al.*, 2024).

MATERIALS AND METHODS

Research approach

It was an applied method qualitative study. In this type of research plan, qualitative data are prioritized to gain a deeper, more nuanced understanding of the issues and the nature of the topic (Creswell and Poth, 2016). Qualitative research methods, unlike quantitative approaches, prioritize flexibility in procedures, especially regarding sampling, as highlighted in various research papers. The decision to utilize qualitative methods is often driven by the aim to select participants who possess firsthand knowledge of the phenomena under investigation, facilitating a deeper understanding of the topic

and ensuring relevant responses from the sample group. This method is particularly recommended due to its alignment with the study's objectives and the emphasis on internal judgment, allowing for a more nuanced exploration of complex issues. Unlike quantitative studies that follow structured procedures, qualitative research offers a more adaptable and participant-centered approach, enabling researchers to delve into the intricacies of human experiences and behaviors within specific contexts (Palalic, 2017). Interviews have always been the staple of qualitative research methods in management studies, and in particular for research dealing with organizational change. Interview-based studies have addressed issues such as sensemaking, emotions, job transition, change agency, and identity in the context of change (Langley and Meziani, 2020). Therefore, this study has been done using Grounded Theory. Grounded theory is a systematic and qualitative method that, at the conceptual level, describes an action, process, or reaction to a real subject. This description was created using the research participants' perspectives (Creswell and Tashakkori, 2007); this method employs an inductive set of procedures to develop a theory about a phenomenon. The primary goal of this type of theorizing is to explain a phenomenon by defining its key elements (concepts, categories, and propositions) and then categorizing the communications of these elements within the context and process of that phenomenon. This method aims to learn about and comprehend people's perceptions of incidents and occurrences in a particular setting (Corbin and Strauss, 2008). To develop a model of apology, the goal of this study is to know and understand people's experiences and interpretations in the area of apology.

Data collection

In the present study, to identify and then develop a model of human resources apology, the opinion of managers was collected through the interview method. The statistical population included human resource managers who have more than 5 years of experience in municipalities, and theoretical saturation was used to confirm the number of samples. According to researchers, in a carefully conducted study with evolutionary sample selection and follow-up, the saturation point could be reached with about 13 participants, which would most likely not exceed 20 (Maykut and Morehouse, 2002). This type of sampling

is known as theoretical sampling in grounded theory. In this type of sampling, the researcher collects, encodes, and analyzes data while simultaneously deciding what to collect in the future and where to find it to improve his theory until it emerges (Glaser and Strauss, 2017). In this study, there were 13 samples. Semi-structured interviews utilizing the 5W1H technique were employed to gather data, with a qualitative coding method utilized for analysis. The focus of the interviews was on human resources apologies within organizational communication, with the sequence of questions varying among participants based on the interview process, lacking a pre-determined pattern in question design. This approach aligns with the importance of understanding the nature of transgressions and forgiveness dynamics within specific cultural contexts to enhance organizational outcomes. Additionally, cultural differences in apology behaviors and intentions in the workplace were highlighted, emphasizing the significance of appropriate apologetic behavior in maintaining stable interpersonal relationships in a globalized workplace setting (Hennink et al., 2020).

The researchers aimed to conduct qualitative interviews independently and explanatorily, focusing on gathering data without bias from previous findings and analyzing the outcomes without preconceived notions. These interviews were carried out through individual meetings held in person in February 2024, following a procedure that continued until reaching theoretical saturation. In this particular study, the questions were structured around the six wh-question marks: how, what, why, when, where, and who, emphasizing a comprehensive exploration of the participants' perspectives and experiences. This approach aligns with the principles of qualitative research, which prioritize open-ended inquiries and an in-depth understanding of the subject matter without imposing predetermined frameworks or mental models. There were six questions in this stage; for instance, "What experiences have you had with the apology phenomenon?", "What are your observations of people who apologize?", "In your opinion, what factors influenced this process?" "What are your observations of the apology process?", "What do other people in the organization look like to people who apologize?" and "How do you see the role of the organization in this process?". The interviews conducted in the study lasted for an average duration

of 80 minutes, with a range from 50 to 180 minutes, exceeding the initially stated 40-60 minutes. The research employed open, axial, and selective coding processes for data analysis, ensuring a comprehensive approach to understanding the information gathered. This methodology allowed for a thorough exploration of the participants' perspectives and experiences, contributing to the richness and depth of the data collected. By utilizing these coding techniques, the study aimed to capture a wide range of insights and nuances from the interviews, enhancing the overall quality and validity of the research findings.

RESULTS AND DISCUSSION

Data analysis

The study conducted on Iranian municipalities utilized a design approach to develop and assess models. Grounded theory, as proposed by [Corbin and Strauss \(2008\)](#), was employed for data analysis, focusing on research questions through open, axial, and selective coding stages. This methodology allowed for a comprehensive exploration of the model development and assessment processes within the municipalities. By following the grounded theory premise, the researchers were able to delve deeply into the data, ensuring a thorough analysis and understanding of the intricate dynamics involved in the research. The structured approach of open, axial, and selective coding facilitated a systematic and rigorous examination of the research questions, leading to valuable insights and robust conclusions regarding the models developed and assessed in the context of Iranian municipalities.

Preparing a preliminary list of human resources apologies in organizational communication using individual interviews

The phase involves conducting interviews to identify key elements of human resources apologies in organizational communication, with insights gathered from managers' perspectives and synthesized into an initial list. Theoretical saturation was achieved after 13 interviews, each transcribed

by a specialist for further analysis. Interviewers reviewed the transcripts, incorporating feedback and refining the content to ensure accuracy and formality, converting spoken language into a more structured format. This meticulous process of data collection and transcription, followed by thorough review and refinement, is crucial in extracting comprehensive and reliable components of organizational apologies in human resources, contributing to a deeper understanding of effective apology strategies in organizational settings ([Andrews et al., 2020](#)). Some instances of verbal expressions or identifying codes are illustrated in [Table 1](#).

Comparing the obtained list with the lists and the pattern of human resources apology in organizational communication

In the qualitative data analysis process, open coding and selective coding are utilized, with these stages often overlapping and occurring concurrently. Initially, key themes are identified and labeled, leading to the development of corresponding categories. Subsequently, a core category is derived by examining the interconnections among the primary categories, potentially resulting in the formulation of a theory to shed light on the subject matter. Despite the potential theoretical implications, the open coding phase involves extracting numerous codes to capture the breadth and depth of the data, allowing for a comprehensive exploration of the information at hand. This systematic approach to coding and analysis is fundamental in qualitative research, guiding researchers from data collection to the generation of meaningful insights and theoretical frameworks ([Dalal and Priya, 2016](#)). In the research process described, a systematic approach to open coding was employed, involving data collection within the study setting and external analysis. The meticulous assessment of data led to the extraction of the ultimate code by integrating open codes into the researcher's notes, followed by axial coding where codes were categorized and relationships explained

Table 1: Open coding

Interview Text	Primary Codes
An apology means that we accept that what we have done is wrong, and to satisfy the other party, we apologize to at least compensate for the blow to the other party with words.	Accepting the wrong An apology to the victim's satisfaction Wrong compensation

through selective coding. Researchers compared primary codes with previous studies to identify new components, which were then added to the list of human resources apologies in organizational communication. The final list of extracted codes was formed after content review and analysis, with all transcripts stored in Atlas ti8 for data analysis support. Interactive and recursive processes, along with a higher level of abstraction in coding, were applied until significant abstract categories were fully unified, culminating in the development of a coherent theory (Corbin and Strauss, 2008). Fig. 1 indicates the relationship between different steps of data analysis and data collection procedures.

Defining human resources apology in organizational communication concepts

This step includes researchers evaluating human resources apology in organizational communication assigned to lists No. 1 and 2. After integrating the results of the interviews into other resources, the final draft of the human resources apology in organizational communication index was formed. The categorization of extracted codes was performed using conceptual correspondence.

Evaluating and refining the list of human resources apologies in organizational communication

The study utilized a narrative approach for individual interviews and the Delphi method for

model development, starting with forming a Delphi panel and identifying samples while explaining the research objectives. Managers were invited to provide feedback on proposed components, leading to the development of a questionnaire based on literature and exploratory interviews for municipalities. The managers then offered constructive feedback on the questionnaire, resulting in the final model of human resources apology in organizational communication with 15 dimensions and 126 selected codes. Data saturation was reached in the interviews, allowing for categorization into different groups (Table 2).

The authors sought to utilize process theory to address issues related to organizational apologies in communication, emphasizing potential interactions over time. Process theory, known for explaining change and development over time, contrasts with grounded theory, which is more inductive, starting with data to build theory. While process theory is deductive, beginning with a conceptual framework and testing it, grounded theory focuses on inductively developing new theories from data (Cloutier and Langley, 2020). By applying process theory to the study of organizational apologies, the authors aimed to provide effective solutions and insights into how these interactions evolve and impact organizational communication strategies over time, contributing to a deeper understanding of crisis management and reputation repair in various contexts. The study delves into the various aspects of human resources

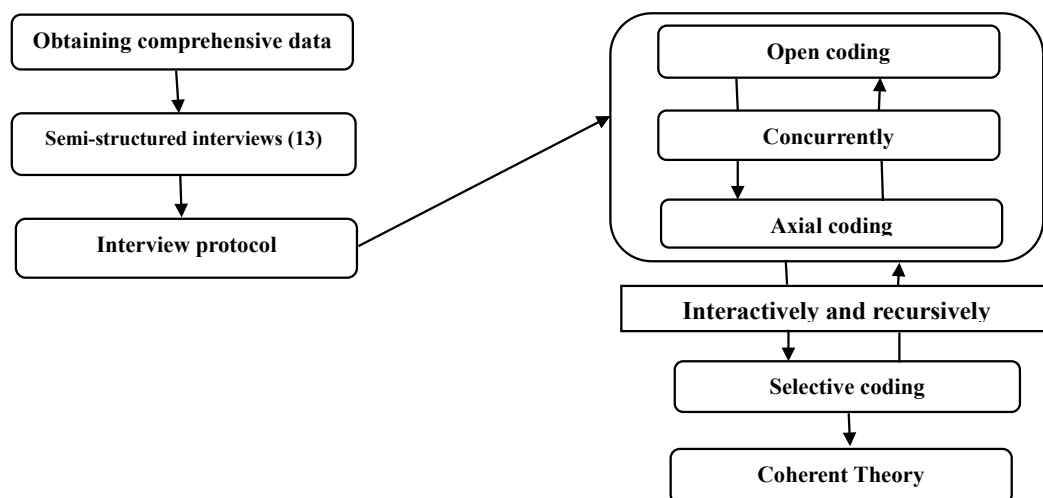


Fig. 1: The relationship between different steps of data analysis and data collection (Hosseini et al., 2022)

apology within organizational communication processes in Iranian municipalities, encompassing interactional strategies, primary phenomena, causal conditions, and the development context and consequences of these strategies. It elucidates the content and multidimensional process of human resources apology in organizational communication, presenting corresponding propositions and a comprehensive process model depicted in Fig. 2. This research sheds light on the intricate dynamics of human resources apology within the organizational communication framework, offering valuable insights into how these elements interplay in the context of Iranian municipalities. This study aimed to propose

a framework for human resource apologies within organizational communication in Iran, making significant theoretical advancements in the field. Beyond theoretical contributions, the research emphasizes the importance of managerial support for human resource apologies, highlighting the need for a unified conceptualization in this area. By utilizing the grounded approach by [Corbin and Strauss, \(2008\)](#), the study suggests that a cohesive understanding of human resource apologies can create valuable opportunities for interdisciplinary collaboration and further advancements in the literature, ultimately benefiting organizational practices.

Causal conditions are a set of events and conditions

Table 2: Dimensions and components extracted from the interviews

Class	Dimension	Components
Causal Conditions	Conflict Management	Compromise Job requirements
	Shortcomings of Individual Behavior	Personal Aggression Poor performance
	Political Behavior	Utilitarianism Impression management
	Motivation	Identified regulation Introjected regulation Apologist personality
	Audience Power	Formal power Personal power
	Acceptability of the Apology	Sincerity of apology Apology content
Context	Apology Method	Concealment of apology Apology tool
	Apology Graph	Apology orientation Apology as a domino in the organization
	Audience Identity	Biographical features Personality Affect Psychological maturity
Intervening Conditions	Quality of Communication	Subject and scope of injury Entanglement of the sides Entry of mediator Situation of apology
Phenomenon	Apology	Apology event
Strategies	Patience	Fairness Compassion
	Incompatibility	Rejection of apologies Destruction of apologist
	Social Capital	Cohesiveness in organization Repairing the relationship Maintain and restore credit
Consequence	Improving Attitude	Disambiguation The happiness of the parties
	Complications Of Apology	Creating inappropriate thoughts in the audience The audience's profit-making actions Mental damage to the apologist

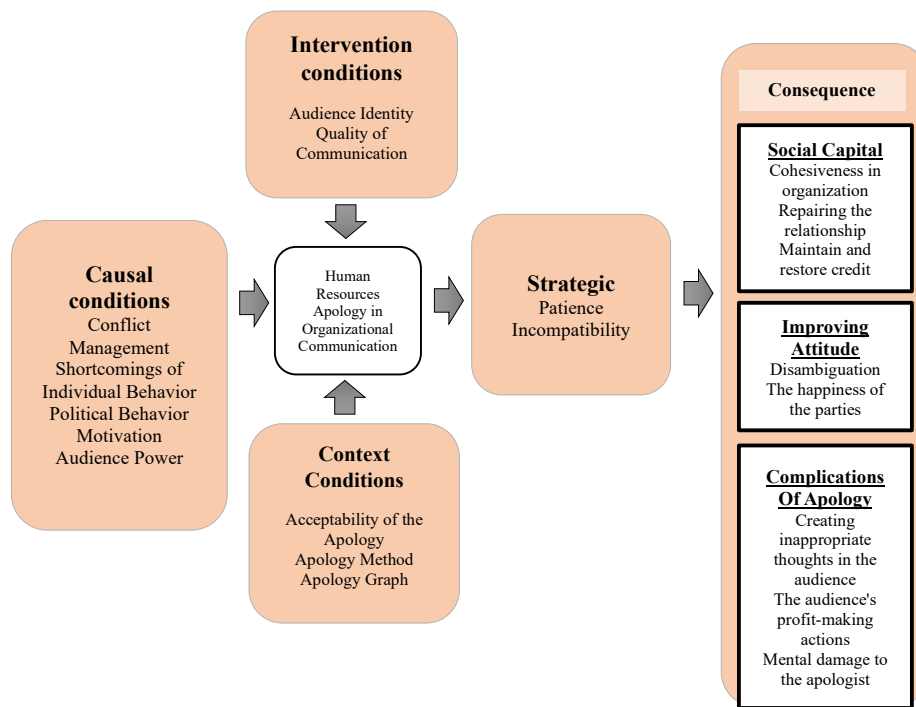


Fig. 2: Coherent process model of human resources apology in organizational communication

that affect the central category and create the phenomenon. People apologize to control and resolve disputes between themselves and their colleagues; they try to calm down the situation and prevent adverse consequences of a continuous conflict. In the current research, conflict management is when a person withdraws from his position to seek compromise and accepts part of the responsibility for the conflict. On the other hand, the audience also gives satisfaction to friendly relations and ending disputes so that a balance is formed between the parties (Chaudhry and Burdea, 2023). Sometimes, despite being determined to achieve their goals or carry out their duties, one may need to apologize due to work obligations that require them to make an effort to maintain cooperation with their colleagues (Gliksion and Asscher, 2023). Therefore, with an apology, they try to consider the interests of their colleagues and make it possible to continue their cooperation. (Job requirements). In some cases, a person may disregard the principles of ethical behavior and the rights of the other party and harm them with their inappropriate behavior (personal aggression) (Gillespie and Berry, 2023). Alternatively, they may have failed to perform their official duties correctly and

completely due to a lack of knowledge or unintentional incompetence (weak performance) (Nosratirad, 2023). In either case, they can apologize, as these factors are considered shortcomings in personal behavior. This study suggests that individuals use apologies as a tool to secure their interests. People may use apologies to advance their careers within an organization or protect their current job position (Utilitarianism) (Wang et al., 2023). They may also apologize to create a positive image of themselves as a responsible and reliable employee in the mind of their supervisor or colleagues (Impression Management) (Seiter et al., 2023). All of these cases refer to the political behavior of individuals when they use apologies. Motivation has also been identified as one of the causes of people apologizing in organizations. The source of a person's motivation and tendency to apologize can be internal (personality) or external (identified regulation) which is demonstrated because of family education and following the example of supervisors (Fehr and Gelfand, 2010). It might be interjected regulation where the person has acted as an external representative and has emotionally encouraged and punished himself for the behavior that others consider appropriate or inappropriate, that is, in

this case, the person is due to factors such as guilt, fulfillment of obligations, feeling of compulsion, obligation and starts apologizing. Audience power refers to his ability to influence the behavior of the apologist this ability can be caused by the person's position in the organization (formal power) or by himself (personal power). The higher the level of this power, the more a person feels helpless or has the desire to apologize. Strategies are based on actions and reactions to control, manage, and deal with the desired phenomenon. In this research, the meaning of strategies is how the audience reacts to the apology of the apologetic person. Strategies include two categories: "patience" and "incompatibility". In the state of patience, a person tries to be fair and just in dealing with the apologist, or to a greater extent, he tries to make the apologist a subject of his compassion. Here, patience refers to the audience's patience and flexibility in responding to the apologist (Zammit Young, 2023). Inconsistency occurs when the audience is unwilling to agree and compromise with the apologist and opposes or destroys him. In the concept of rejecting an apology, the audience refrains from accepting the apology. He may explain his opposition to him calmly and only by turning away from the apologist, or he may be aggressive toward him out of anger (Gillespie and Berry, 2023). Another form of inconsistency can be more crushing, in which the audience tries to destroy and belittle the apologist. To destroy the apologist, the audience mocks, taunts, or humiliates him. Intervening conditions are structural conditions that belong to the phenomenon in question and affect action and reaction strategies. These conditions refer to individual's attitudes, characteristics, and beliefs that distinguish them from others. Apologies are effective in eliciting a response from an individual about their identity. More experienced, older, and better-educated individuals tend to respond to apologies with greater composure (biographical characteristics). To the extent that the audience has more etiquette and self-restraint, the degree of anger is moderated when receiving an apology (Thompson, 2019). However, their sensitivity may increase their resistance to accepting an apology. If the recipient cannot receive an apology, it can lead to undesirable reactions from them (personality). When an individual is experiencing intense emotions due to their mistake, an apology at that moment may not elicit the desired response (Lazare, 2005). On the other hand, if the mistake is in an area where the recipient has biases, their ability to

accept the apology is reduced (Affect). If the recipient has not fully matured psychologically, they may not respect the rights of the apology in their response (Psychological maturity) (Risen and Gilovich, 2007). The quality of the relationship between the audience and the apologist affects the communication process. The more the mistake is related to the recipient's priorities, values, and organizational position, the more difficult it is for them to accept the apology (Subject and scope of injury). If both parties have a close relationship or the recipient needs the apologist's assistance, their reaction may be less severe (Entanglement of the sides). When an apologist is unable to face the recipient due to their mistake, they may use an intermediary to soften the situation. In most cases, respect and closeness with the intermediary improve the situation and create opportunities for negotiation, and conflicts are usually resolved with an apology. Another scenario is when a colleague or a supervising manager voluntarily intervenes in the situation and personally apologizes, thereby putting the relationship between the parties in a state of excuse and willingness to end the issue, leading to their acceptance of the apology (entry of mediator). Passing a significant amount of time since the wrong reduces the power and likelihood of its acceptance. Rushing to apologize in the heat of the moment also leads to an undesirable reaction. Relative time in the result of apology has a positive effect. In a proper and fair apology, the individual must apologize in front of the same audience who was harmed by their actions to restore their reputation (Situation of apology). The context is a set of special characteristics that indicate the desired phenomenon and influence the strategies. Here, including three categories; "apology acceptability", "apology method" and "apology graph". The more acceptable and desirable the apology is, the more positive the response will be. Honesty in an apology has a positive relationship with its acceptance. Instrumental and superficial apologies, if perceived as credible by the recipient, are also positively received (Sincerity of apology). Mixed apologies that contain sarcasm or non-acceptance are not effective, while those made as a formality are usually considered accepted (Apology content). Besides, when a person tries to apologize covertly or openly, and what tools she uses to apologize, all of these factors (Dimension and Components identified by the authors) including the way she apologizes, can affect the audience's response. In mathematics, a graph means a non-zero set of nodes (vertices) and a

set of edges that connect the vertices. These edges representing connections can be directional. The apology graph refers to the relationship between people and their apologies. This category consists of two concepts: apology and the domino-like effect of apology between people. Within organizations, most apologies come from lower levels to higher levels and are often seen as a duty, with a higher probability of non-acceptance. The power to influence apologies from higher to lower levels is greater. Although they can sometimes be perceived as insolent or arrogant, they are generally accepted (Apology orientation) (Mifune *et al.*, 2019). On the other hand, within the hierarchy of an organization, there is a chain of apologies. When a person makes a mistake in performing their duties, they should apologize to their manager, and the department manager should apologize to their higher-level manager, and so on in a continuing chain. Early notification of the mistake to the manager can moderate their reaction. Another scenario is a chain of apologies among victims. This chain can take shape between individuals who have a working network, regardless of organizational hierarchy. The fact that one person's mistake disrupts another person's tasks and ultimately forces them to apologize to the next person in the chain can lead to an undesirable reaction to the previous person's apology (apology seems Domino in the organization) (Bentley, 2018). Consequences are the results obtained from the strategies and actions related to the desired phenomenon. The consequence of the apology and the victim's reaction includes three categories "strengthening social capital", "improving attitudes" and "complications of apology". Apologizing strengthens social capital because creating cohesion in the organization is one of the consequences of apologizing in the organization. Organizational cohesion means the dependence of people on the organization and the existence of extensive communication between the people of the organization and between people and the organization. On the other hand, when a person apologizes, he conveys his desire to restore what was lost from the relationship to the audience. If he succeeds in getting his satisfaction, he can restore the relationship to a large extent. Furthermore, when the person apologizes, justifies the audience regarding his good intentions, and ensures that it will not happen again in the future, he/she restores the feeling of security in the relationship with the audience, and it can win back his trust. By

apologizing, the person makes it clear to him that he is sorry for the mistake and trying to improve the situation. Therefore, the audience gets a more complete and positive understanding of what happened and what the apologist is looking for now. Apologizing is correct and improves the perceptions and thoughts of the audience about the mistake. In addition, when the person apologizes, the audience can understand the regret and the effort to improve the situation and compensate for the mistake, which creates a feeling of peace and he will be satisfied and the audience's attitude will improve. On the other hand, apologizing is like a double-edged sword that has disadvantages along with its advantages. Another part of the consequences of an apology is related to its complications. Apologies can create inappropriate thoughts in the audience, so that the audience may consider the apology as an action due to the weakness of the apologist and cause the person to consider himself superior to the apologist and create the impression in the audience that he is always right and used the person's apology to exploit, constantly blame or magnify the image of the apology received by others and in this way, use the received apology to his advantage.

Limitations and future studies

The study aimed for perfection within its limitations, as qualitative data collected from interviews with managers in Iranian municipalities may introduce subjectivity into the analysis and model extraction. While efforts were made to mitigate these limitations through managerial collaboration, the reliance on subjective perceptions could impact the objectivity of the conclusions. Extending the study to diverse companies in Iran could yield varied and potentially less reliable results, highlighting the need for caution in generalizing findings beyond the specific organizational context of municipalities in Iran. It is suggested that for future research in organizational studies, a study be conducted to identify supportive factors and institutionalization strategies for apologies and to examine the topic of apologies in inter-group and inter-organizational relationships. It is also proposed to present a process model for theory building in non-apology and to provide a typology for apologies as a potential research topic. Additionally, a questionnaire can be designed and a quantitative study can be conducted to validate the presented model and expand the discussion of apologies in other statistical societies.

CONCLUSION

The ultimate objective of this qualitative research was to develop a model of human resources apologies in organizations. According to a review of the research literature, several studies have examined the influence of certain factors on apologies. However, this study is distinct because it applied the Grounded Theory to observe means of apologizing in the form of an integrated process for the first time. The components of an apology show that an apology is not always just the use of the word "sorry". It includes other things that show apologetic feelings, specify the rights of the parties, and predict and direct the future behavior of the apologist. Hence, an apology is not an act limited to the moment of its execution. The simplest and most common way that people express their regret is by employing a clichéd and repeated term (illocutionary force indicating device) that expresses regret, such as excuse me, I'm sorry, I want an excuse, etc. And this is how he introduces the apology. During an apology, when wrongdoers first define and explain what they consider a mistake to the audience (confession of wrongdoing) to show their understanding of their mistake and the damage to the audience. Apologizing for an action and repeating it at the same time is meaningless and does not evoke the concept of a proper apology. It can be said that one of the most crucial components of an apology is the commitment of the apologist not to repeat his mistake in the future. This point can facilitate attracting the audience and accepting an apology from his side. Besides, it can motivate him to overlook the mistake and give the audience a sense of security in future events. The apologist expresses regret and sadness (sympathy with the audience) for the harm he caused to the audience with his actions, whether psychological or situational and caused him to suffer. Apologizing while the audience feels that the apologist does not understand imposed harm might cause him to perceive indifference. It can further destroy his damaged emotions. In cases where the harm caused to the audience was unknown or unintentional, the apologist tries to explain the disinterestedness of his action to the audience and thus prevent the destruction of his attitude towards himself. On the other hand, the apologist tries to explain his reasons for making the mistake as long as the audience accepts that the damage was unintentional (emphasis on the impartiality of the mistake); it increases his ability to forgive and bear the damage. The apologetic person explains all his regret for the action and the damage

caused to the audience, in such a way that he feels all the feelings of regret both in the face and speech of the apologetic and in his behavior (expressing regret). When compensating for the mistake, the apologist tries to take the necessary measures to correct the problem and compensate for the damage caused to the audience.

AUTHOR CONTRIBUTIONS

A.R. Rajabipoor Meybodi, M. Sabokro, and A. Solhjo author performed the conceptualization and literature review and compiled the data. E. Hosseini and F. Forghani Elahabadi author performed the manuscript preparation, methodology, analyzed, and prepared the manuscript text, and edited references.

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CONFLICT OF INTEREST

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

PUBLISHER'S NOTE

Tehran Urban Research & Planning Centre (TURPC) takes a neutral position about claims on disputed territories, place names, international boundaries, jurisdiction in published maps, and institutional affiliations. TURPC is committed to retracting a paper after its publication if it becomes apparent that there are serious problems in its content, in terms of research and publication ethics (<https://www.ijhcum.net/journal/process?ethics>).

ABBREVIATIONS (NOMENCLATURE)

5W1H	What, Where, When, Why, Who(m), How
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ORIGINAL RESEARCH PAPER

Effect of technology application in enhancing the weaknesses of market access, financial resources, and supplier resources on the aluminum industry

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ABSTRACT

BACKGROUND AND OBJECTIVES: A grasp of economic development is essential to comprehending policies and initiatives that support industrialization and the fight against poverty. It can assist in identifying areas for additional investment and growth and serve as a guide for planning, carrying out, and assessing economic development efforts. Bumiputera entrepreneurs encounter many obstacles to market accessibility, restricted financial means, and insufficient supplier networks, which may impede the expansion and prosperity of their businesses. The utilization of technology is essential in mitigating these shortcomings, allowing Bumiputera entrepreneurs to surmount obstacles and attain enduring prosperity in the aluminum sector. Entrepreneurs can create strong supplier networks, maximize the use of financial resources, and improve market access by utilizing technology. The purpose of this research is to examine how technology applications might mitigate the limitations of market access, financial resources, and supplier resources that impede the success of Bumiputera entrepreneurs in the aluminum sector. The growth and profitability of Bumiputera businesses can be inhibited by several obstacles, including restricted supplier networks, insufficient financial resources, and difficulty accessing markets.

METHODS: The quantitative research approaches and methods can help provide a comprehensive understanding of the mediating effect of technology in enhancing market, finance, and supplier resource weaknesses for the success of Bumiputera entrepreneurs in the aluminum industry. An explanatory research design is a type of research design that focuses on the variables that determine the mediating effect of relationships and explains the causes and effects of the variables defining the phenomenon to be studied. The data was analyzed using SMART PLS3. The study was conducted specifically on Bumiputera entrepreneurs in the aluminum industry. Data from the Bumiputera aluminum industry was gathered through purposive sampling. As a minimal 75 sample size, a total of 80 questionnaires were distributed to Bumiputera respondents who have been working in the Malaysian aluminum industry. As a response, a 93.75% rate was achieved, and we dedicated a week in May 2023 to data collection.

FINDINGS: Out of ten (10) hypotheses, only six (6) were valid, while the remaining four were ruled out. The recent high cases of the COVID-19 pandemic in 2019 have had an impact on them. The findings of this study contribute to the academic literature by highlighting the importance of technology in facilitating the success of Bumiputera entrepreneurs in the aluminum sector.

CONCLUSION: The study empirically confirms and conceptually proves that the policies of industry associations and organizations ("Skim Jaminan Modal Kerja—Bumiputera", the "Business Act 1956, and the Financial Procedure Act 1957) can advocate for policies that support Bumiputera entrepreneurs in accessing technology and improving their market access, financial resources, and supplier resources. The key technologies and strategies that help these entrepreneurs build thriving businesses offer recommendations for policymakers, business leaders, and entrepreneurs to support and promote success among this essential group of entrepreneurs. By lobbying for supportive policies, the industry can create an enabling environment for Bumiputera entrepreneurs to leverage technology effectively and overcome their weaknesses.

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INTRODUCTION

According to a report by Grand View Research, the global aluminum market is expected to grow at a Compound Annual Growth Rate (CAGR) of 5.9% from 2020 to 2027. This growth is part of the increased demand for aluminum in the automotive, aerospace, and construction industries. In Malaysia, the aluminum industry has been identified as a primary sector for economic growth, and the government has implemented several initiatives to support the development of Bumiputera entrepreneurs in the industry (Hamid *et al.*, 2019; Sabiu *et al.*, 2018; Safaruddin *et al.*, 2019). National Development Strategy provides financing and other forms of support to Bumiputera entrepreneurs in the industry (Hamid *et al.*, 2019). In addition, there is an increasing focus on advancing digital capabilities and technologies, which can enable Bumiputera entrepreneurs to overcome many of the challenges they face in the industry (Adrutdin *et al.*, 2020). For example, digital platforms can provide access to market intelligence and business support services, while advanced manufacturing technologies can improve the efficiency and competitiveness of operations. Recent research (Kamarudin *et al.*, 2019) suggests that there is a strong need for continued investment in the development of Bumiputera entrepreneurs in the aluminum industry. It includes the need for tailored training and development programs that address specific challenges faced by these entrepreneurs, as well as increased access to financing and other forms of support (Amesheva *et al.*, 2019). According to a report by the Ministry of International Trade and Industry (MITI) in Malaysia, successful Bumiputera entrepreneurs in the industry have focused on product differentiation, quality, and cost-effectiveness. The government has several measures and programs to help Bumiputera entrepreneurs access the aluminum market. These include trade and investment missions to specific nations, business matching services, and market intelligence. Some Bumiputera entrepreneurs lack the technical expertise required to effectively evaluate their suppliers and identify the most suitable suppliers for their business (Orrensalo *et al.*, 2022). Next is limited production capacity. It is because of the limited resources that some Bumiputera entrepreneurs may be unable to produce sufficient quantities of aluminum products to meet demand or to compete effectively with larger firms in the industry

(Kamarudin *et al.*, 2019). Another research said that limited transportation options (Guo *et al.*, 2023) in transporting raw materials and finished products. Overall, the limited availability of supplier resources can pose a significant challenge for Bumiputera entrepreneurs in the aluminum industry, impacting their competitiveness and growth (Kamarudin *et al.*, 2019). Moreover, it provides insights into effective strategies that policymakers and industry stakeholders can adopt to support the development of these entrepreneurs and to foster growth and competitiveness in the industry (Bărbulescu *et al.*, 2021; Veleva, 2021). The weakness faced by Bumiputera entrepreneurs in the aluminum industry is the limited availability of supplier resources (Er *et al.*, 2019). Limited access to raw materials is one of the main issues Bumiputera entrepreneurs confront in this area (Gayatri, 2021), and face difficulty in obtaining access to raw materials for aluminum production (Lewicka *et al.*, 2021). Other than that, it is because of limited technical capabilities in the aluminum industry (Yu *et al.*, 2021). Overall, this study contributes to a deeper understanding of the factors that underpin the success of Bumiputera entrepreneurs in the aluminum industry in Malaysia and may inspire future research in this area. This study has significant implications as it extends the current body of knowledge on the challenges and success factors of Bumiputera entrepreneurs in the Malaysian aluminum industry by highlighting the potential mediating effect of technology application in 2023.

Literature review

The aluminum industry is rapidly evolving, with new technologies emerging. Bumiputera entrepreneurs may be unable to keep up with these changes due to a lack of knowledge or resources (Aizuddin *et al.*, 2020). A study highlighted the potential of Industry 4.0 technologies to empower Bumiputera entrepreneurs in the aluminum industry (Suradi *et al.*, 2017). It was an argument that technologies such as additive manufacturing, robotics, and the Internet of Things could help improve productivity and efficiency and enhance these entrepreneurs' ability to compete in the global market. It found that digital technologies such as e-commerce and digital marketing could help improve Bumiputera entrepreneurs' access to the global market and enhance their competitiveness

(Rahim *et al.*, 2019). The benefit of digital technologies may be essential for supporting access to market resources for Bumiputera entrepreneurs in the aluminum industry. The use of e-commerce platforms was positively associated with the export performance of small and medium-sized enterprises in Malaysia (Amornkitvikai *et al.*, 2022). Bumiputera entrepreneurs can seek reliable suppliers to offer competitive prices and timely material delivery (Azeez *et al.*, 2020). Bumiputera entrepreneurs must build strong relationships with their suppliers to ensure a steady and reliable supply of raw materials. To reduce their dependence on a single supplier or type of raw material, Bumiputera entrepreneurs can diversify their supplier base. They can source raw materials from multiple suppliers or countries to minimize the risk of supply disruptions (Althaf *et al.*, 2021). For strategic sourcing, Bumiputera entrepreneurs can adopt a strategic sourcing approach to optimize their supply chain and reduce costs. They can identify the most cost-effective sources of raw materials and negotiate better deals with suppliers (Benton, 2020). One key variable of technology application that can help enhance Bumiputera entrepreneurs' success in the aluminum industry is Industry 4.0. Industry 4.0 technologies, including automation, artificial intelligence, and the Internet of Things (IoT), can enable Bumiputera entrepreneurs to streamline operations, increase efficiency, and reduce costs (Guzmán-Ortiz *et al.*, 2020). Thus, by using technology to monitor supplier performance, reduce lead times and costs, and improve inventory management, Bumiputera entrepreneurs can enhance their competitiveness and efficiency. Supply chain challenges were a significant barrier to success for Bumiputera Small and Medium-sized Enterprises (SMEs) in the Malaysian aluminum industry, highlighting the importance of addressing this variable through technology application (Cheong *et al.*, 2020). Bumiputera Agenda Steering Unit (Abdul Hamid *et al.*, 2023), training and capacity building programs can help to address challenges such as the lack of technical expertise and knowledge gaps in manufacturing processes, leading to more effective adoption of technology. Economic development can help to address this challenge by providing access to alternative sources of capital, such as crowdfunding, venture capital, and microfinance. Access to capital is a critical factor in the success of more than 70% of SMEs in the Pakistani aluminum industry (Wu *et al.*,

2021). Market linkages and networking opportunities are other variables that can be promoted through economic development initiatives (Shkabatur *et al.*, 2022). More study is needed to identify how Bumiputera entrepreneurs can access market knowledge and compete in international markets (Yap *et al.*, 2023). Bumiputera entrepreneurs may face additional challenges related to environmental sustainability (Abd Shukor *et al.*, 2022). Research is needed to identify the climate sustainability challenges by Bumiputera entrepreneurs in the aluminum industry and initiatives to promote sustainable practices (Yeow, 2022). Therefore, there is a need for research on the mediating effect of technology application in enhancing the weakness of the market, finance, and supplier resources throughout Bumiputera entrepreneur's aluminum success.

MATERIALS AND METHODS

Survey design and data collection

Quantitative methods were applied to collect data on factors such as market access, financial resources, supplier resources, technology application, and economic development. Self-administered questionnaires were used to collect data in this study. The mediating effect of technology application in the aluminum sector on the dimensions of the deficiencies that constitute barriers to economic development among Malaysian Bumiputera entrepreneurs was examined using an explanatory study design. It has been decided that this kind of research will be carried out as part of a deductive study or quantitatively based association with a survey strategy to determine the impact of technology use in a particular environment. This study used Bumiputera entrepreneurs in the aluminum sector as its unit of analysis. This particular set of businesses is especially well-suited for the study since they frequently encounter obstacles when improving their suppliers, markets, and financial resources. In this study, cross-sectional time was applied to provide an opportunity to collect relevant data and analyze the effect of technology use on the success of Bumiputera entrepreneurs in the aluminum industry (Bell *et al.*, 2022). The study employed a non-probabilistic-purposive sampling plan for data collection. The maximum number of independent and mediating variables, or arrows, pointing towards a construct in this study is six. Hence,

75 samples with a 0.25 R-square value and a 5% risk of error are required to reach a statistical power of 80%. Eighty questionnaires were given to Bumiputera respondents who had been employed in Malaysia's aluminum industry since the sample size was only 75. It looks like it took a week in May 2023 to achieve a 93.75% rate in response to receiving the data. The sample selection is crucial to accurately represent the studied population and prevent bias, which can impact the validity and reliability of the research results. The statistical power significantly influences the reliability and validity of results in Partial Least Squares Structural Equation Modeling (PLS-SEM). Average Variance Extracted (AVE) is a percentage ranging from 0% to 100%, calculated by combining the variance of each measurement item from the construct variance and dividing by the total variance. The value produced is a percentage ranging from 0% to 100%, with values above 50% being considered acceptable for reliability analysis. Cross-loading on multiple factors can compromise the discriminant validity of an item, making it less reliable and valid. An item with high loading values on two factors can be analyzed for collinearity issues or theoretical basis, and if not justified, removed or revised to measure only one construct. However, for this particular study, the survey approach is the most suitable for gathering data by utilizing structured questionnaires,

and survey respondents provide information. This method is appropriate for investigating the mediating effect of technology application as it allows for quantitative data collection, which can be analyzed using statistical methods. In this day of digitalization, self-administered online surveys are a common way to gather data. Numerous advantages come with using online questionnaires, including affordability, adaptability, and simplicity of use. Researchers found that administering a self-administered online questionnaire to participants in the comfort of their own homes or offices at their convenience is a popular way to collect data. The respondents participated in an online survey that Google Forms hosted using Telegram and WhatsApp. Sections A, B, C, D, E, and F are essential for obtaining valid and reliable data from the respondents to address the research objectives. The questionnaire must be designed to ensure that the questions are unbiased, easy to understand, and relevant to the research objectives.

Analytical framework

Fig. 1 illustrates how technology application mediates the impact of market access, financial resources, and supplier resources on the success of Bumiputera entrepreneurs in aluminum.

The conceptual framework (Fig. 1) shows the mediating effect of technology application in enhancing

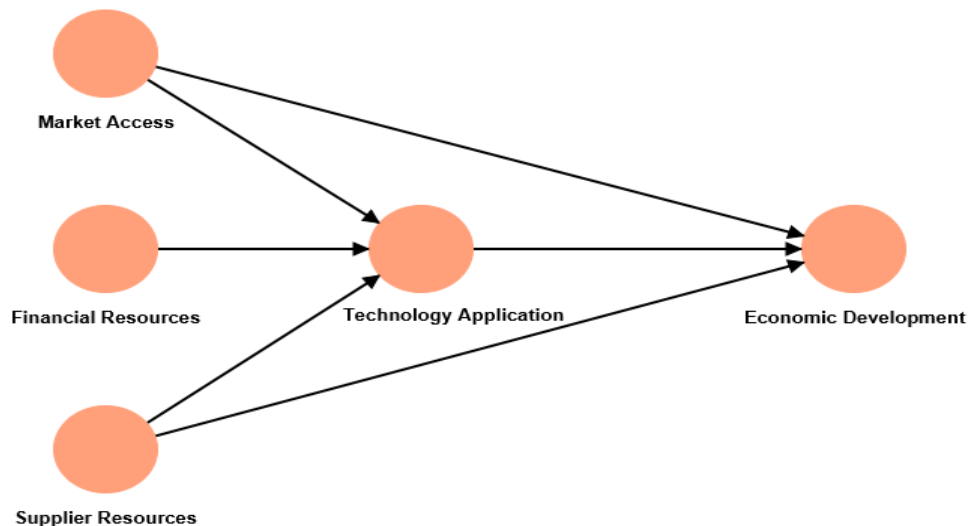


Fig. 1: Conceptual framework of technology application in enhancing the weakness of market access, financial resources, and supplier resources

the weakness of market, finance, and supplier resources throughout Bumiputera entrepreneur's aluminum success can be supported by Bumiputera success theory. For Bumiputera entrepreneurs in the aluminum industry, understanding market theory can help them make strategic decisions about pricing, production levels, and marketing (Ali *et al.*, 2021; Wirtz *et al.*, 2021). One essential concept in market theory is supply and demand. Bumiputera entrepreneurs should carefully monitor market conditions and adjust their production and pricing strategies accordingly (Roknifard, 2023). Another essential concept in market theory is competition. In the aluminum industry, Bumiputera entrepreneurs may face competition from both domestic and foreign companies. To remain competitive, they may need to innovate and offer unique products or services that distinguish them from their rivals (Algarni *et al.*, 2023). Nevertheless, the market theory emphasizes the importance of customer satisfaction. Bumiputera entrepreneurs should strive to meet the needs and expectations of their customers by offering high-quality products, excellent customer service, and competitive prices. Bumiputera entrepreneurs in the aluminum industry in Malaysia may face challenges in accessing markets due to various reasons like language barriers, lack of understanding about export-import procedures, and limited access to financial resources (Weed, 2023). To overcome these challenges and improve their market access, Bumiputera entrepreneurs in the aluminum industry in Malaysia may need to develop effective marketing strategies, expand their network, and seek out government support (Whah, 2017). Market access theory is applied to Bumiputera entrepreneurs in the aluminum industry in Malaysia since their success may depend on access to domestic and international markets. Moreover, they can seek government support to finance their marketing efforts, increase competitiveness, and connect with potential buyers (Khan *et al.*, 2021). Research into the experiences of Bumiputera entrepreneurs in Malaysia suggests that market access can be a significant challenge, particularly for those who are operating SMEs (Mohamad *et al.*, 2021). Thus, understanding the dynamics of market access and developing successful strategies to address these challenges may improve their ability to compete and succeed in the aluminum

industry in Malaysia. Therefore, the Resource-based view theory suggests that these entrepreneurs can gain a competitive advantage in the aluminum industry in Malaysia by developing and utilizing unique resources and capabilities (Hossain *et al.*, 2022). Some of the resources and capabilities that may contribute to the competitive advantage of Bumiputera entrepreneurs in the aluminum industry in Malaysia include access to government contracts, local knowledge and networks, financial backing, and innovation used in aluminum materials (Leckel *et al.*, 2020). In the aluminum industry, Bumiputera entrepreneurs may rely on external resources such as aluminum suppliers, government contracts, and employees with technical expertise. To mitigate these challenges, Bumiputera entrepreneurs in the aluminum industry in Malaysia may need to develop strong relationships with their suppliers, seek out alternative external resources, and collaborate with other firms in the industry (Abdullah, 2006). It may help them to reduce their dependence on any single external resource and increase their chances of survival and success in the industry. The hypotheses are based on the theoretical framework and foundation of the research:

- H1: *There is a positive relationship between market access and economic development*
- H2: *There is a positive relationship between financial resources and economic development*
- H3: *There is a positive relationship between supplier resources and economic development*
- H4: *There is a positive relationship between market access and technology application*
- H5: *There is a positive relationship between financial resources and technology application*
- H6: *There is a positive relationship between supplier resources and technology application*
- H7: *There is a positive relationship between technology application and economic development*
- H8: *Technology application mediates the relationship between market access and economic development*
- H9: *Technology application mediates the relationship between financial resources and economic development*
- H10: *Technology application mediates the relationship between supplier resources and economic development*

RESULTS AND DISCUSSION

Descriptive statistics and analysis for variables entering the analysis

Table 1 shows the distribution of 75 randomly selected Bumiputera entrepreneurs in the aluminum industry in Malaysia. Out of 75, there were 73 male (97.3%) and two (2) female (2.7%) of Bumiputera entrepreneurs. Therefore, most of these entrepreneurs were male. Table 1 indicates that out of 75 sample Bumiputera entrepreneurs, there were 33 (44.0%) of the entrepreneurs aged between 35 to 44 years old, and 25 (33.3%) between 45 to 54 years old. Then, there were 9 (12.0%) in between 55 years old and over. Last but not least, 8 of 75 (10.7%) samples were at the age of 25 to 34 years old. It shows that most of the entrepreneurs are middle-aged between 35 to 44 years old. The results also show that out of 75 samples, almost three-quarters of them were the owner and founder of the company Aluminum 54 (72.0%) were entrepreneurs, 10 (13.3%) were the employees, 7 (9.3%) were the manager and director and the rest of 4 (5.3%) were the executive and supervisor. It found that those who were other than

the owner of the Bumiputras' aluminum company were the ones who were dabbling in the world of aluminum business. The results also show most of the companies were established with less than 10 of the manpower 67 (89.3%), 7 (9.3%) in between 10 and 49, and only 1 (1.3%) company had the manpower around 500 and above.

Reflective measurement model results

Reliability analysis

A reliability test is a statistical measure used to determine the consistency and stability of a measurement instrument used in research. One general method of assessing reliability is through Cronbach's alpha coefficient. Cronbach's alpha is a coefficient that measures the internal consistency of a measurement instrument (Cronbach, 1951). It indicates the extent to which all items on a scale measure the same underlying construct. Typically, a Cronbach's alpha coefficient of 0.7 or above is considered acceptable. Based on Table 2, economic development has an AVE value of 0.854, financial resources value is 0.602, market access is 0.739,

Table 1: Result of the respondent's profile

Demographic	Category	Frequency	Percent (%)
Age	25-34	8	10.7
	35-44	33	44.0
	45-54	25	33.3
	55 or over	9	12.0
Gender	Male	73	97.3
	Female	2	2.7
Education	High school diploma or less	32	42.7
	College/technical school	17	22.7
	Associate's degree	1	1.3
	Bachelor's degree	17	22.7
	Master's degree	8	10.7
Experience	Less than 1 year	27	36.0
	1-5 years	31	41.3
	6-10 years	10	13.3
	11-15 years	1	1.3
	More than 15 years	6	8.0
Size	Less than 10	67	89.3
	10-49	7	9.3
	500 or more	1	1.3
Role	Owner/Founder	54	72.0
	Manager/Director	7	9.3
	Executive/Supervisor	4	5.3
	Employee	10	13.3

supplier resources are 0.744, and technology application is 0.771. The resulting value is a percentage that ranges from 0% to 100%, with values above 50% considered acceptable.

Construct validity

Table 3 results demonstrate that there was

some discriminant validity, except for economic development (0.924), which has a higher value than technology application (0.878) and market access (0.859). Discriminant validity is essential because it allows researchers to distinguish between different concepts and ensure that their research is accurately measuring the construct that they

Table 2: Result of the reliability analysis

Construct	Measurement item	Outer loadings	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
ED	ED1	0.954	0.965	0.970	0.972	0.854
	ED2	0.938				
	ED3	0.927				
	ED4	0.977				
	ED5	0.889				
	ED6	0.854				
FR	FR1	0.517	0.863	0.886	0.899	0.602
	FR2	0.793				
	FR3	0.806				
	FR4	0.794				
	FR5	0.852				
	FR6	0.844				
MA	MA1	0.773	0.929	0.933	0.944	0.739
	MA2	0.844				
	MA3	0.896				
	MA4	0.879				
	MA5	0.873				
	MA6	0.885				
SR	SR1	0.781	0.930	0.938	0.946	0.744
	SR2	0.851				
	SR3	0.865				
	SR4	0.946				
	SR5	0.879				
	SR6	0.845				
TA	TA1	0.858	0.941	0.944	0.953	0.771
	TA2	0.823				
	TA3	0.894				
	TA4	0.908				
	TA5	0.903				
	TA6	0.881				

*ED = Economic Development; FR = Financial Resources; MA = Market Access; SR = Supplier Resources; TA = Technology Application

Table 3: Discriminant validity – Fornell – Larcker criterion

	ED	FR	MA	SR	TA
ED	0.924				
FR	0.760	0.776			
MA	0.826	0.814	0.859		
SR	0.707	0.841	0.734	0.863	
TA	0.840	0.798	0.788	0.835	0.878

intend to measure. Tests of the correlation between measures of various constructs are a popular way to evaluate discriminant validity. If two constructs are highly correlated, then their measures do not have discriminant validity. Nonetheless, their measures possess discriminant validity if they exhibit minimal correlation.

Cross-loading analysis

Table 4 shows that the loading of each statement towards its latent variable is greater than that of the other construct. It indicates that the data used to support the loading of each statement towards its latent variable is valid in terms of its ability to distinguish between different constructs. Cross-

loading of an item is problematic because it can lead to a lack of discriminant validity, thereby resulting in a measure that is less reliable and less valid. When an item shows significant loadings on multiple factors, it indicates that the item is not uniquely measuring a particular variable, but instead measuring more than one construct. As a way to tackle the problem of cross-loading items, it should analyze the factor loadings of each item on different factors, as proposed by (Kline, 2023) in his publication. If an item loads on two variables that have high loading values, it is included in several constructs based on theory or if it is related to collinearity problems. There is no theoretical basis for the item that might be changed or eliminated to measure just one construct.

Table 4: Cross-loading analysis

	ED	FR	MA	SR	TA
ED1	0.954	0.738	0.845	0.660	0.828
ED2	0.938	0.733	0.818	0.637	0.815
ED3	0.927	0.735	0.784	0.696	0.814
ED4	0.977	0.753	0.796	0.715	0.814
ED5	0.889	0.637	0.677	0.639	0.696
ED6	0.854	0.599	0.634	0.563	0.673
FR1	0.425	0.517	0.400	0.314	0.406
FR2	0.562	0.793	0.647	0.649	0.613
FR3	0.616	0.806	0.699	0.741	0.599
FR4	0.694	0.794	0.756	0.712	0.613
FR5	0.568	0.852	0.566	0.646	0.636
FR6	0.648	0.844	0.679	0.759	0.778
MA1	0.590	0.584	0.773	0.591	0.592
MA2	0.633	0.723	0.844	0.647	0.664
MA3	0.767	0.724	0.896	0.649	0.748
MA4	0.755	0.702	0.879	0.594	0.643
MA5	0.745	0.758	0.873	0.663	0.712
MA6	0.749	0.695	0.885	0.641	0.692
SR1	0.560	0.684	0.600	0.781	0.621
SR2	0.559	0.755	0.661	0.851	0.677
SR3	0.630	0.766	0.696	0.865	0.694
SR4	0.733	0.818	0.707	0.946	0.834
SR5	0.613	0.665	0.574	0.879	0.741
SR6	0.544	0.658	0.558	0.845	0.732
TA1	0.790	0.763	0.756	0.775	0.858
TA2	0.608	0.619	0.563	0.633	0.823
TA3	0.748	0.687	0.691	0.730	0.894
TA4	0.793	0.782	0.751	0.788	0.908
TA5	0.737	0.674	0.681	0.698	0.903
TA6	0.727	0.658	0.684	0.755	0.881

*Structural model results**Collinearity assessment*

The Inner Variance Inflation Factor (VIF) is a measure of multicollinearity in a regression model. Multicollinearity occurs when the independent variables in a regression model are highly correlated with each other. The precise impact of each independent variable on the dependent variable becomes difficult to ascertain in these circumstances, and standard errors of estimates may be computed incorrectly. The inner VIF is used to identify the degree of multicollinearity between the independent variables in a regression model. It measures the degree to which the variance of an independent variable is inflated due to its correlation with other independent variables in the model.

Path coefficients

Table 6 displays six structural equation models supporting the hypotheses, while the remaining four do not support them. The effect between supplier resources and economic development was significant ($\beta = 0.452$, $t = 4.564$, $p < 0.05$). Thus, H1 was supported, as were the six hypotheses (H1, H4, H6, H7, H8, and H10). The p-value was higher than 0.05 outside the 95% confidence interval, indicating that the remaining four hypotheses (H2, H3, H5, and H9) were not sufficiently unsupported. From the coefficient summary, the technology application has a huge effect on economic development ($\beta = 0.563$, $t = 3.409$, $p < 0.05$). Path coefficients can be seen as the slope of the relationship between two variables in the model. They represent the degree

Table 5: VIF Values for the structural model

	ED	FR	MA	SR	TA
ED	0	0	0	0	0
FR	0	0	0	0	4.774
MA	2.779	0	0	0	3.034
SR	3.472	0	0	0	3.501
TA	4.224	0	0	0	0

Table 6: Path coefficients

	Hypothesis	Path coefficient	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values
H1	MA -> ED	0.452	0.642	0.621	0.141	4.564	0.000
H2	FR -> ED	0.057	0.057	0.079	0.102	0.563	0.573
H3	SR -> ED	-0.095	0.188	0.190	0.128	1.466	0.143
H4	MA -> TA	0.337	0.337	0.320	0.150	2.253	0.024
H5	FR -> TA	0.102	0.102	0.128	0.158	0.645	0.519
H6	SR -> TA	0.502	0.502	0.495	0.140	3.580	0.000
H7	TA -> ED	0.563	0.563	0.553	0.185	3.049	0.002
H8	MA -> TA -> ED	0.190	0.190	0.170	0.095	2.002	0.045
H9	FR -> TA -> ED	0.057	0.057	0.079	0.102	0.563	0.573
H10	SR -> TA -> ED	0.283	0.283	0.271	0.119	2.370	0.018

to which a unit change in the predictor variable (independent variable) results in a unit change in the criterion variable (dependent variable) when all the other variables in the model are held constant. Path coefficients are standardized to have a mean of zero and a standard deviation of one, allowing for easy comparison of the strength of the relationships between different sets of variables in the model. The sign of the path coefficient indicates the direction of the relationship - a positive coefficient indicates a positive relationship and a negative coefficient indicates a negative relationship. The significance of the path coefficients is determined using p-values, which indicate the probability of observing a coefficient value at least as extreme as the one in the sample if the null hypothesis (no relationship between variables) is true.

The findings are presented in Table 7, which demonstrates that H1 was supported and so were the six hypotheses (H1, H4, H6, H7, H8, and H10). The rest of the four hypotheses H2, H3, H5, and H9 were not sufficiently unsupported because the p-value is greater than 0.05 which does not match the 95% confidence level.

The technology application has the largest effect on economic development ($\beta = 0.563$, $t = 3.409$, $p < 0.05$). The finding for hypothesis 1 showed that ($t = 4.564$, $p < 0.05$) which is positively influenced between market access and economic development. In the case of Bumiputera Entrepreneurs Aluminum's success in Malaysia, several studies have shown that greater market access leads to positive economic outcomes. Perhaps market access allows enterprises to access new customers, suppliers, and technologies, which

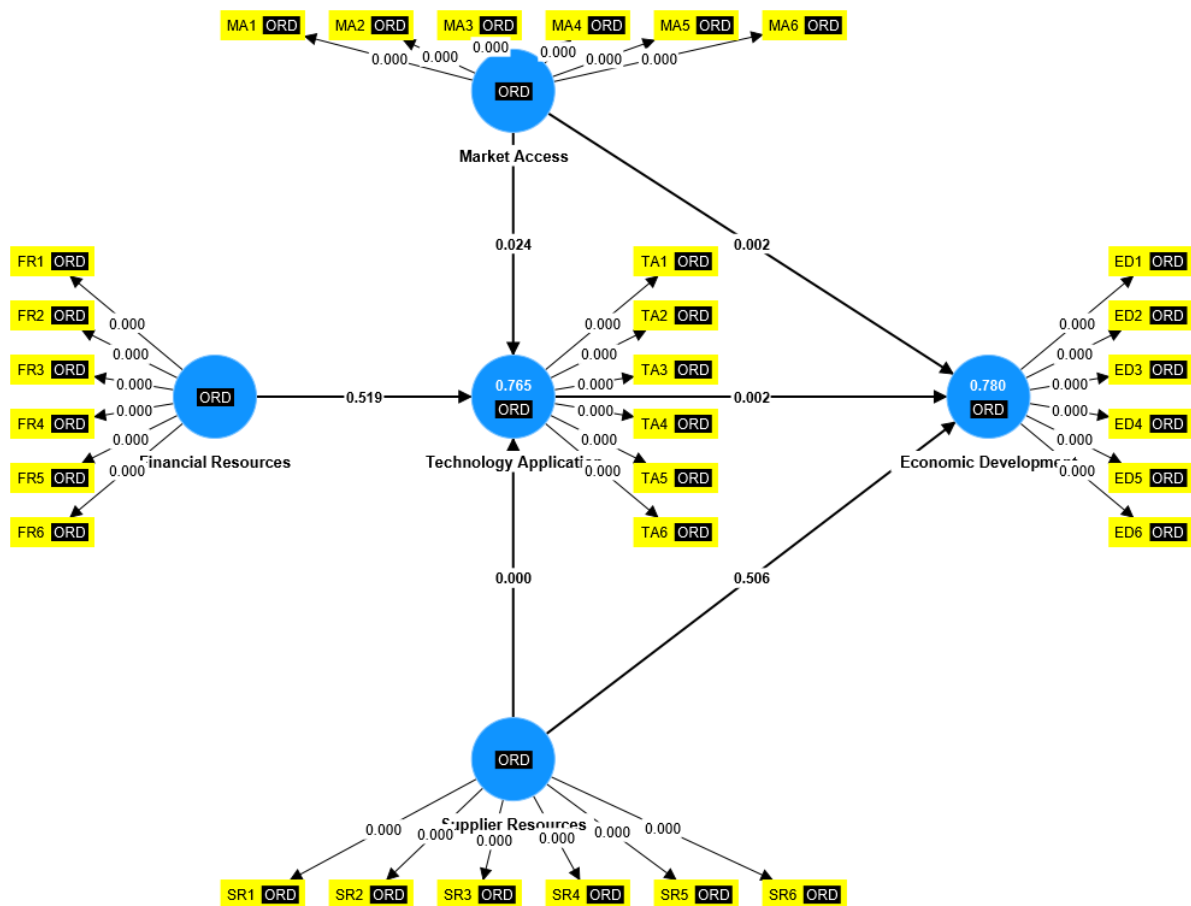


Fig. 2: The structural model-path coefficients

Table 7: Summary of discussion findings

Item	Hypothesis	T statistics (O/STDEV)	P values	Decision
H1	There is a positive relationship between market access and economic development	4.564	0.000	Accepted
H2	There is a positive relationship between financial resources and economic development	0.563	0.573	Rejected
H3	There is a positive relationship between supplier resources and economic development	1.466	0.143	Rejected
H4	There is a positive relationship between market access and technology application	2.253	0.024	Accepted
H5	There is a positive relationship between financial resources and technology application	0.645	0.519	Rejected
H6	There is a positive relationship between supplier resources and technology application	3.580	0.000	Accepted
H7	There is a positive relationship between technology application and economic development	3.049	0.002	Accepted
H8	Technology application mediates the relationship between market access and economic development	2.002	0.045	Accepted
H9	Technology application mediates the relationship between financial resources and economic development	0.563	0.573	Rejected
H10	Technology application mediates the relationship between supplier resources and economic development	2.370	0.018	Accepted

helps them to expand, innovate, and increase their revenues. Another study by [Mohamad et al., \(2022\)](#) found that the ability of SMEs to access international markets is a significant contributor to economic growth and development in Malaysia. The study highlights that market access can help to increase competitiveness, productivity, and employment opportunities. For H4, the result indicated significant due to market access and technology applications ($t = 2.253$, $p < 0.024$) that are crucial for the success of any business. The study noted that Bumiputera entrepreneurs had better access to local and global markets while having higher sales revenue and better economic performance. It suggests that market access is positively related to economic development and Bumiputera entrepreneurs' success in the aluminum industry. Another study found that the application of technology, specifically e-commerce and online marketing, was positively related to Bumiputera entrepreneurs' aluminum success ([Gomez et al., 2017](#)). Furthermore, e-commerce platforms provided Bumiputera entrepreneurs with new market opportunities, expanding their reach and increasing sales revenue ([Fauzi et al., 2023](#)). Rather than that, H6, H7, H8 and H10 showed a significant result (H6: $t = 3.580$, $p < 0.000$), (H7: $t = 3.049$, $p < 0.002$), (H8: $t = 2.002$, $p < 0.045$) and

(H10: $t = 2.370$, $p < 0.018$) in this study because in a study by [Gomez et al. \(2020\)](#), supplier resources, including timely delivery, quality of raw materials, and technical support have a significant impact on the adoption and successful implementation of technology by Bumiputera aluminum entrepreneurs. It has been highlighted in the study that it is crucial to establish a strong relationship with the suppliers and invest in their capability development. Moreover, a study by [Kuriakose et al., \(2022\)](#) suggests that technology can help Bumiputera entrepreneurs achieve better inventory control, more efficient production processes, and improved supply chain optimization, leading to increased profitability and economic growth. The research found that by adopting technological innovations such as automation, big data analytics, and the Internet of Things, SMEs in the aluminum industry can improve their supply chain management, increase efficiency, and better access supplier resources, leading to economic development. Additionally, the Malaysian government has implemented initiatives to support technology adoption and supply chain development. For example, the Malaysia Digital Economy Corporation (MDEC)'s Digital Transformation Acceleration Program provides guidance and funding opportunities for SMEs in the aluminum industry to

adopt new technology platforms, enhance supply chain management, and improve access to supplier resources. The findings also showed insignificant toward H2, H3, H5 and H9. The result for hypothesis 2 which is $t = 0.563$, $p < 0.573$ is not supported toward financial resources and economic development because, without adequate capital, businesses may struggle to maintain operations, pay employees, and invest in new opportunities. As a result, a lack of financial resources may negatively impact businesses' success and hinder economic development in the long run. A study found that despite government initiatives to provide incentives and financial assistance to small businesses, many Bumiputera entrepreneurs faced challenges accessing funding during the pandemic (Joremi *et al.*, 2023). For H3, the $t = 1.466$, $p < 0.143$ showed that the hypothesis was rejected due to an insignificant relationship between supplier resources and economic development. A study found that many SMEs in Malaysia, including Bumiputera-owned businesses, struggled to secure supplies during the pandemic due to increased demand and disrupted supply chains (Youssof *et al.*, 2023). This lack of access to supplier resources leads to a decline in production and sales, ultimately impacting businesses' success and economic development. Nevertheless, hypothesis 5 indicated rejection of financial resources and technology application due to limited financial resources that negatively impact the adoption of Industry 4.0 technologies, such as automation and artificial intelligence (Bag *et al.*, 2021; Jamwal *et al.*, 2021), among Bumiputera entrepreneurs in the aluminum industry. The study noted that these technologies require insignificant investments, which may not be feasible for Bumiputera entrepreneurs with limited financial resources. It implies that limited access to financial resources hinders technology adoption, potentially hindering their aluminum businesses' success and economic development. Parenthetically, hypothesis 9 also showed rejection because technology application does not mediate the relationship between financial resources and economic development ($t = 0.563$, $p < 0.573$). Business Loan Guarantee Scheme, the Malaysian government provides access to finance to SMEs to invest in technology and other development activities. The government also runs programs that provide technical assistance in technology adoption, such as the Malaysia Productivity Corporation's

Manufacturing Advisory Service Program. Meanwhile, Bumiputera entrepreneurs can still adopt technology with limited financial resources, leading to enhanced efficiency, quality, competitiveness, and economic development.

Practical and Policy recommendation

By contributing financially, the industry can facilitate the research process and ensure its successful completion. Researchers can benefit from the industry's sharing of pertinent data and insights. It may involve exchanging supplier, financial, and market data. The sector can help researchers gain a thorough grasp of the difficulties faced by Bumiputera entrepreneurs and how technology can assist in overcoming those difficulties by granting access to such data. Industry associations and organizations can advocate for policies that support Bumiputera entrepreneurs in accessing technology and improving their market access, financial resources, and supplier resources. By lobbying for supportive policies, the industry can create an enabling environment for Bumiputera entrepreneurs to leverage technology effectively and overcome their weaknesses. Industry experts can collaborate with researchers by sharing their knowledge and expertise on technology applications in the aluminum industry. Bumiputera entrepreneurs face specific challenges that can be understood through insights. Technology can be leveraged effectively to address these challenges. This collaboration can help ensure that the research findings are relevant and practical. "Tabung Pembangunan Usahawan Bumiputera" is a specialized financial institution that offers financial assistance and support to Bumiputera entrepreneurs in various industries. They provide financing options like business loans, working capital loans, and trade financing to qualified entrepreneurs, including those in the aluminum industry. This study highlights the benefits of implementing BPMB, which offers tailored financing solutions and business support to Bumiputera aluminum industry entrepreneurs. Support for bumiputera entrepreneurs in the aluminum industry, including coaching, training, and consulting, enhances their capabilities, preparing them for market challenges and sustainable growth.

Limitation and future recommendation

In the diligence of the researcher in conducting

the study, several limitations have occurred. Firstly, there was a limited time to complete and reach the target. During this limited time, there was only a collection of small samples of approximately 75 Bumiputera entrepreneurs from the participants of Furniture Industry Technology Centre Sdn Bhd who had done the course on aluminum products. As noted, the model's core focus was the relationship between one mediator without demographical factors and dependent and independent variables. Thus, on further analysis, the researcher could include those factors in the model structure. The research also used questionnaires as the only data collection tool, although there are various data collection tools. Future research might consider other data collection techniques such as interviews, focus groups, etc. Such an approach would increase the scope of research and a deeper understanding of the research topic.

CONCLUSION

After evaluating the entire learning from this study, the Business Act 1956 and the Financial Procedure Act 1957 are used as recommendations and references to improve the economic improvement of the aluminum industry towards the Bumiputera in Malaysia. According to sources from the Contractor Service Center of the Ministry of Entrepreneur Development and Cooperatives, the Bumiputra certificate recognition guide for Government work procurement is used as a reference for Bumiputra aluminum entrepreneurs in Malaysia. It is the guidance for Bumiputera entrepreneurs who have high chances of opportunities to develop an aluminum business in Malaysia. The guidance indicates that Bumiputera entrepreneurs have significant opportunities to improve their aluminum business in Malaysia. This guidance aligns with the Bumiputera Development policy in Malaysia under the Financial Procedures Act 1957 (Act 61) and Treasury Circular PP/PK 1.1 Article 6 (iv), which aims to ensure fair work distribution policies by the government. "Skim Jaminan Modal Kerja – Bumiputera" (SJMKB) was introduced into Malaysia's 2023 budget under the Business Act 1956, Act 197. This scheme necessitates the registration of the company ownership type. The scheme is a government guarantee scheme to help SME companies. Bumiputera entrepreneurs gain access to financing facilities from the Financial Institutions involved to increase achievement to a higher level.

The main objective of this financing is to provide aid to micro businesses in various sectors, including retail, manufacturing, and services, to encourage young entrepreneurs to establish their ventures. To this end, the "Program Pembangunan Usahawan Teknikal" has been initiated, which offers funding for machinery and equipment purchasing with a 40% funding grant, provided the repayment record is consistent and good. In addition, the "Skim Pembiayaan Perniagaan Mudah Jaya" has been introduced to provide business financing facilities to Bumiputera entrepreneurs in main sectors such as trade, services, and manufacturing, except for agriculture and animal husbandry. They also have business advisory services to support entrepreneurs in developing their business strategies, improving operational efficiency, and improving overall business performance. It guides in various areas, including business planning, market entry strategies, financial management, and export assistance. Advisory services can help entrepreneurs make informed decisions, address challenges, and exploit opportunities in the aluminum industry.

AUTHOR CONTRIBUTIONS

M.S. Mohamad Salleh performed the literature review, and experimental design, analyzed and interpreted the data, and H. Vasudevan prepared the manuscript text, and manuscript edition. M.S. Mohamad Salleh and H. Vasudevan performed the experiments and literature review, compiled the data and manuscript preparation. M.S. Mohamad Salleh performed the data analysis and findings while H. Vasudevan compiled the data analysis and findings for the manuscript edition.

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CONFLICT OF INTEREST

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

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ABBREVIATIONS

$\bar{Y}$	Average of observed data
R^2_{adj}	Adjusted coefficient of determination
$\bar{Y}$	Average of observed data
AVE	Average variance extracted
BPMB	Tabung Pembangunan Usahawan Bumiputera
TA	Technology Application
R^2	Coefficient of determination
CAGR	Compound Annual Growth Rate
ED	Economic Development
HP	Hypothesis
IoT	Internet of Things

α	Level of significance
FR	Financial Resources
FITEC	Furniture Industry Technology Centre
MA	Market Access
MITI	Ministry of International Trade and Industry
MDEC	Malaysia Digital Economy Corporation
SR	Supplier Resources
TA	Technology Application
<i>p-value</i>	Probability value
PLS SEM	Partial Least Squares Structural Equation Modeling
PUTEK	Program Pembangunan Usahawan Teknikal
<i>r</i>	Pearson correlation coefficient
<i>r-value</i>	Pearson correlation coefficient
SPiM	Skim Pembiayaan Perniagaan Mudah Jaya
SMEs	Small Medium Enterprises

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REVIEW PAPER

Bibliometric analysis of research trends in Green Human Resource Management and sustainable development

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ABSTRACT

The adoption of sustainable development goals by the United Nations in 2015 has led to an increasing focus on sustainable development and green practices among academics and private industry professionals. This study aims to explore the research landscape of "Green Human Resource Management" and "sustainable development". Despite the increasing attention in recent years, the field remains in its infancy. To gain insights, five research questions were formulated and addressed using descriptive and network analyses. Applying descriptive statistics reveals that the fields of research on "sustainable development" and "Green Human Resource Management" encompass eight different subject areas, indicating the multifaceted and expansive nature of these subjects. Beyond 2020, a noteworthy rising trend in publications is noted. Having contributed 22 articles since the field's inception, the Journal of Cleaner Production stands out as a major publication source. Developing nations such as Malaysia, China, and India are leading in research contributions, indicating a strong inclination towards sustainable practices. Brazil stands out with the highest citation count, attributed to its significant environmental challenges. Network analysis identifies prominent themes and their interconnections. Thematic evolution analysis shows substantial growth in literature from 2015 to 2023, with organizational sustainable performance and supply chain management emerging as significant themes in recent years. Notably, authors Jabbour CJC, De Sousa Jabbour, and Latan H. are highlighted for their prolific contributions, particularly in the early stages of "Green Human Resource Management" and "sustainable development" literature. This study provides valuable insights for management professionals and researchers by highlighting influential articles, authors, sources, countries, and affiliations. It is a comprehensive reference for understanding the evolving landscape of Green Human Resource Management and sustainable development literature. Additionally, it emphasizes the need for continuous research and collaboration to address environmental challenges and promote sustainable business practices globally.

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INTRODUCTION

People are becoming increasingly aware of the environmental impact and resource depletion resulting from their daily actions (Pinzone *et al.*, 2016). This heightened consciousness has not only motivated individuals but also stakeholders of organizations to embrace more sustainable business practices (Jabbour, 2015; Joshi and Dhar, 2020). Various countries and international organizations have identified sustainable development and subfields like renewable energy and climate change as top national priorities (Sims, 2004; Sanaeepur *et al.*, 2013). Consequently, governments, regulators, and agencies are encouraging companies to adopt environmentally responsible business practices (Das, 2002; Prakriti, 2023) leading to the establishment of frameworks such as the United Nations Global Compact (UNGC), Sustainable Development Goals (SDG), Carbon Disclosure Project (CDP), and Sustainability Accounting Standards Board (SASB). As per the report by the Intergovernmental Panel on Climate Change (2021), human activity is identified as the primary driver of climate disruption, posing a significant threat to all species on Earth (Hampton, 2015; Tilman and Lehman, 2001; Ukaogo, 2020). Consequently, many organizations have begun to integrate environmentally friendly practices into their operations to mitigate the environmental impact of human activities, giving rise to concepts like green marketing (Kilbourne, 1998), green human resource management (Renwick *et al.*, 2013), and green supply chain management (Fahimnia, 2015). Some studies suggest that environmental management can lead to reduced costs, increased production, and improved brand reputation, thus contributing to both environmental and financial dimensions of sustainability (Ambec and Lanoie, 2008; Miles and Covin, 2000). Wehrmeyer emphasizes the pivotal role of employees in the success or failure of a company adopting an environmentally conscious approach (Wehrmeyer, 1996) thus contributing to the social dimension of sustainability. According to Jabbour, only when Businesses strive to green their practices, they can achieve a triple-bottom-line performance (Jabbour *et al.*, 2012). Thus, Green Human Resource Management (GHRM) will help achieve a triple bottom line by reducing organizations' carbon footprints (Yong *et al.*, 2019). Given the United Nations' pivotal role in the sustainability discourse

and the commitment of 170 nations to achieve the Sustainable Development Goals (SDG) by 2030 (Ferranti, 2019), there has been growing significance in both GHRM as well as sustainable development literature over the past two decades. Recently, the literature on the relationship between GHRM and sustainable development has been emerging (Almagharbeh and Alalean, 2023; Jehan *et al.*, 2020; Obeidat and Abdalla, 2022; Shahzad *et al.*, 2023). This growing significance indicates a need to organize the research findings and highlight current trends in GHRM and sustainable development literature. To achieve this, the study conducts a Bibliometric analysis of "GHRM" and "sustainable development" to examine the evolution of research from 2015 to 2023 and better understand their relationship. The study aims to address the following Research Questions (RQs):

- RQ1: *What are the prevailing patterns in publications concerning GHRM and sustainable development?*
- RQ2: *Which countries and affiliations are making the most significant contributions to research on the relationship between GHRM and sustainable development?*
- RQ3: *What are the prominent themes of GHRM and sustainable development and how they have evolved?*
- RQ4: *Who are the prominent authors and what is the level of connection between different authors?*
- RQ5: *Which are the highly cited works on GHRM and sustainable development and what is their contribution?*

The goals mentioned above are achieved through descriptive and network analysis. The subsequent sections of this paper are structured as follows: The first part details the objectives of conducting a Bibliometric analysis, followed by the second part, which discusses the research methodology employed. The third section presents the results of key Bibliometric indicators and summarizes the findings. Lastly, the conclusion outlines the future research directions.

Literature review

Sustainability has emerged as a pivotal concept across corporate and industrial spheres in recent times (Jabbour, 2018; Lange *et al.*, 2012). The term Sustainability has been defined by many scholars

and global organizations (Basiago, 1995). Sustainable development means making sure we meet our needs now without causing problems for the ability of future generations to meet their own needs (Laranja Ribeiro *et al.*, 2021). It comprises three core dimensions: ecological, economic, and social. The ecological dimension of sustainability focuses on preserving the environment and its resources, while the economic dimension of sustainability aims at promoting growth through technological advancements and increased efficiency in resource utilization. The social dimension of sustainability aims to enhance living conditions and safety for all. These dimensions are often referred to as the triple bottom line or 3Ps: people, profit, and place, and are used interchangeably with social, economic, and ecological (Dariah *et al.*, 2019; Fauzi *et al.*, 2010; Hammer and Pivo, 2017). The concept of sustainable development, ensuring present needs are met without compromising the ability of future generations to meet their own needs, gained global recognition at the UN Conference on the Human Environment in Stockholm in 1972 (Polfeldt, 2006). Subsequent milestones, such as the 1987 World Commission on Environment and Development and the 1992 Rio Summit, further reinforced this principle (Have and Neves, 1992; Hecht, 1992). The 2002 World Summit on Sustainable Development in Johannesburg and the adoption of the 2030 Agenda for Sustainable Development (Hepp, 2019; Tremblay *et al.*, 2020) underscored the importance of sustainable development through political declarations and partnership initiatives (Frantzius, 2004; Schirnding, 2005; Spalding, 2005). The SDGs devised in 2015 address almost all trivial areas that impact human life like Health, Education, Gender equality, Clean energy, and environmental protection (Griggs *et al.*, 2014; Mainali *et al.*, 2018; Morton *et al.*, 2017). GHRM emerges as a potential solution to realize the dimensions of sustainable development. Unlike conventional HRM, GHRM promotes eco-friendly practices such as electronic offices, carpooling, teleconferencing, flexible working hours, and remote work, which contribute to carbon emissions reduction and waste minimization (Ahmad, 2015; Suharti and Sugiarto 2020). Wehrmeyer's work, "Green Policies Can Help to Bear Fruit," integrates environmental management with HRM, making a significant theoretical contribution to the field (Wehrmeyer, 1996). There are various definitions for

GHRM. According to Jabbour, GHRM is the systemic, planned alignment of typical human resource management practices with the organization's environmental goals (Jabbour, 2013). According to Wikhamn, GHRM is the adoption of HRM strategies and practices that enable the inside and outside of the organization over a long-term time horizon while controlling for unintended side effects and negative feedback (Wikhamn, 2019). A widely used definition of GHRM states it is a phenomenon relevant to understanding relationships between organizational activities that impact the natural environment and the design, evolution, implementation, and influence of HRM systems (Ren *et al.*, 2018). GHRM practices encompass building green employee competencies, promoting a green workforce, and offering green jobs (Renwick *et al.*, 2012). These practices aim to utilize resources sustainably and mitigate environmental damage resulting from business operations (Ahmad, 2015). Greening HRM functional dimensions, such as job description and analysis, recruitment, selection, training, performance appraisal, and rewards, is central to GHRM (Jabbour *et al.*, 2010). Some definitions of GHRM emphasize its alignment with the organization's environmental objectives and strategies (Jabbour *et al.*, 2010; Ren *et al.*, 2017). Theoretical perspectives like institutional theory, systems theory, process theory, stakeholder theory, resource-based theory, and Ability Motivation Opportunities (AMO) theory inform GHRM discourse (Arulajah and Opatha, 2016). AMO theory, which focuses on ability, motivation, and opportunity, is particularly relevant to GHRM (Appelbaum *et al.*, 2000; Pinzone *et al.*, 2016; Rayner and Morgan, 2017; Renwick *et al.*, 2013). According to this theory, HRM practices enhance employee motivation, develop their abilities and skills, and provide opportunities for them to contribute fully. GHRM literature contributes to environmental performance as corporate social responsibility (Anwar *et al.*, 2020; Hameed *et al.*, 2022; Jabbour and De Sousa Jabbour, 2016; Umrani *et al.*, 2020). On the other hand, it also modifies employees attitudes toward the environment and improves employee satisfaction and retention (Ari *et al.*, 2020; Briio *et al.*, 2007; Dumont *et al.*, 2016; Tirno *et al.*, 2023; Wilson and Bryant, 1997). Studies have explored specific GHRM practices like green hiring, green training, green teams, green employee engagement, green performance management, and

green skills (Das and Dash, 2023; Xie *et al.*, 2020; Jabbour *et al.*, 2013a; Tariq *et al.*, 2014; Bowen *et al.*, 2018).

MATERIAL AND METHODOLOGY

The study applied bibliometric analysis along with a thorough search strategy to analyze the previous studies. Bibliometric analysis is a crucial tool for researchers to analyze and rank authors, journals, subjects, and nations (Rejeb *et al.*, 2023). Bibliometric research can leverage datasets from databases such as Web of Science, Scopus, Google Scholar, PubMed, Dimensions, SpringerLink, etc. (Cobo *et al.*, 2011). The methodology part can be divided into the following sections. First, the selection of a database (Scopus) and keywords (“green hrm” or “green hr” or “green human resource management” and “sustainable development”) for the study. Second, the inclusion and exclusion criteria to conduct a bibliometric analysis as explained below in Fig. 1. Third, bibliometric tools and techniques to conduct the study. Fourth, Analysis and discussion about the bibliometric data.

Search criteria

For this study, the Scopus database was utilized (Udin, 2023) renowned for its vast collection of

academic works and comprehensive data on journals, countries, authors, affiliations, and references. As a counterpart to Clarivate’s Web of Science, Scopus is particularly valuable for evaluating the impact of social science research (Aznar-Sánchez *et al.*, 2019; Norris and Oppenheim, 2007). The search query used the keywords “green HRM”, “green human resource management”, “green HR” and “sustainable development” to identify relevant documents. The search was limited to articles published between 2015-2023 in the subject areas of Business, Management, and Accounting, and only articles in English were considered. This search strategy resulted in 68 documents. The search query utilized was as follows: TITLE-ABS-KEY (“green hrm” OR “green human resource management” OR “green hr” AND “sustainable development”) AND PUBYEAR > 2007 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA, “BUSI”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”)).

Study selection

For better reproducibility and transparency of the research, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework criteria were employed for study selection (Page *et al.*, 2021). It is stepwise explained in Fig.1 The first

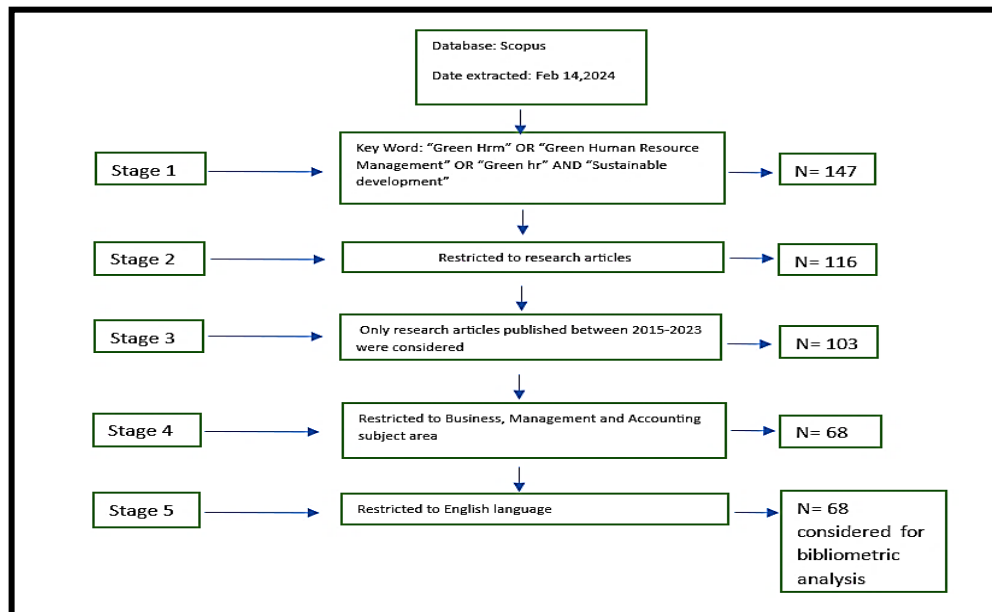


Fig. 1: Search criteria employed in Scopus database (Authors own creation)

step involves the initial keyword search in the Scopus database resulting in 147 documents. The second step involves limiting the source type to research articles, resulting in 116 articles. In the third step, only articles found between 2015-2023 were considered for the study, resulting in 103 articles. In the fourth step, only articles from Business, management, and accounting were considered for the study thus excluding the unrelated domains, and finally, only articles published in the English language were considered for the study. Thus, a final list of 68 articles was identified and considered for the bibliometric analysis.

Bibliometric tools and techniques

The Bibliometric data from the Scopus database was obtained in Comma-Separated Values (CSV) format, providing the necessary metadata for detailed analysis. Biblioshiny, available in the Bibliometrix R package (<https://www.bibliometrix.org/>), was utilized for data visualization and analysis. The open-source environment and comprehensive statistical techniques offered by the Bibliometrix R package make it a preferred choice (Aria and Cuccurullo, 2017). VOSviewer known for its text mining functionality that can be used to construct and visualize co-occurrence networks of keywords was utilized (Van Eck and Waltman, 2009). Pritchard defined bibliometric analysis as the application of statistical and mathematical methods to books and other communication tools (Groos and Pritchard, 1969). Performance analysis and science mapping serve as foundational approaches for bibliometric analysis (Donthu et al., 2021). Performance analysis

aims to assess citation and publication performances to evaluate scientific data in terms of quality and quantity (Ozturk and Dil, 2022). Citation analysis evaluates the effectiveness of obtained research data. Science mapping visually represents collaboration between scientific data such as authors, concepts, and citations, offering insights into the intellectual structure and evolutionary processes of the literature (Masri et al., 2017)

Data overview

To understand the data analysis section more clearly, an overview of the data taken for the bibliometric study is given here. Within 2015-2023, 68 articles were found in the Scopus database on GHRM and sustainable development. The Annual growth rate (%) is 32.5, the Average citation per document is 68.53 and the total number of references from 68 articles is 4972. About the document contents, the keywords plus include 275, Author keywords include 224. When coming to Authors, there are total number of 191 Authors and Authors of single-authored documents is 7. When coming to Co-authorship, Co-authors per doc is 3.18 and International co-authorships (%) is 42.65.

RESULTS AND DISCUSSION

RQ1: Current trend of publication

There has been an increasing need for interdisciplinary approaches to address complex sustainability challenges. This has led to more collaborative research across fields such as environmental science, economics, sociology, and

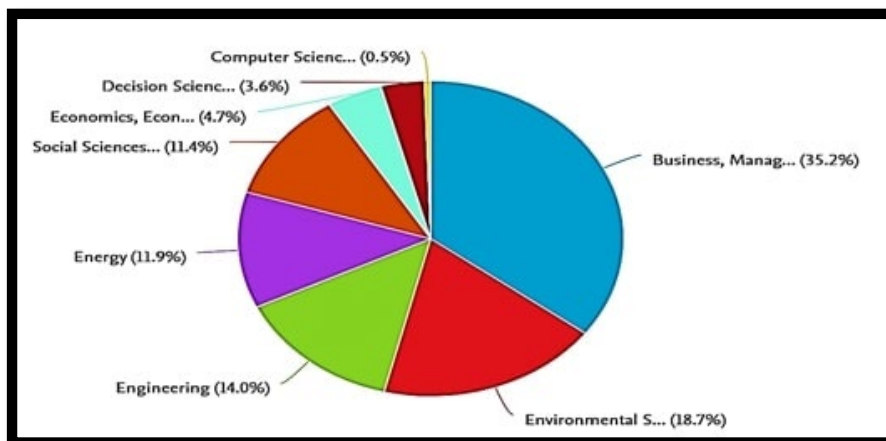


Fig. 2: Dominant domains of GHRM and sustainable development-based research (Scopus database)

business management, contributing to a rise in publications which has resulted in an annual growth rate of 32%. Fig. 2 shows the distribution of articles related to GHRM and sustainable development across 8 different disciplines. The Business and Management domain contributes around 35.2% of the research landscape which indicates a significant focus on the integration of sustainable practices with business management strategies. The second largest contributing domain is Environmental sciences which indicates the close association of green hrM with environmental sustainability. The engineering domain contributes around 14% of the research landscape and may relate to sustainable engineering practices and technologies. The energy domain contributing around 11.9% suggests a substantial interest in the intersection of green hrM and energy sustainability covering issues like energy efficient practices and renewable energy. The Social Science domain contributing around 11.4% suggests the exploration of green HRM practices from a social and behavioral perspective. 3 of the subject areas have less than 10 published articles while 5 of the subject areas have more than 20 published articles.

The yearly publications on GHRM and sustainable development from 2015 to 2023 have been projected in Fig. 3. There are a total of 68 articles published in the Scopus database from 2015-2023. The above chart can be easily split into two demi decades, 2015-2019, and 2020-2023. During the first demi decade, publications were scarce, reflecting the nascent

stage of research in this field. As per the findings of Bahuguna *et al.*, (2022), there is an increase in research publications on GHRM scholarship after 2015. However, the above findings show an increase in publication trend only after 2019. This increasing research trend on GHRM and sustainable development might be because of the cruel impact of COVID-19 on our lives. The following five years (2019-2023) saw a notable increase in the volume of publications, reaching its peak in 2020 and 2023 having the highest number of 18 articles related to green human resource management and sustainable development. Shah (2019) made a significant research contribution by developing a measurement scale for GHRM which is composed of 7 components: green job design, green recruitment and selection, green training and development, green performance management, green compensation management, green health and safety, and green labor relations. This was one of the main reasons for the sudden rise of publications especially empirical works on GHRM of late.

RQ2: Most contributing journals, countries, and their affiliations

Table 1 depicts the top most productive journals, the number of articles, their citations, and h-index in the area of GHRM, and sustainable development. The Journal of Cleaner Production is the highest contributor with 22 articles and the highest citation count (2939) and h-index (19). The journals Business

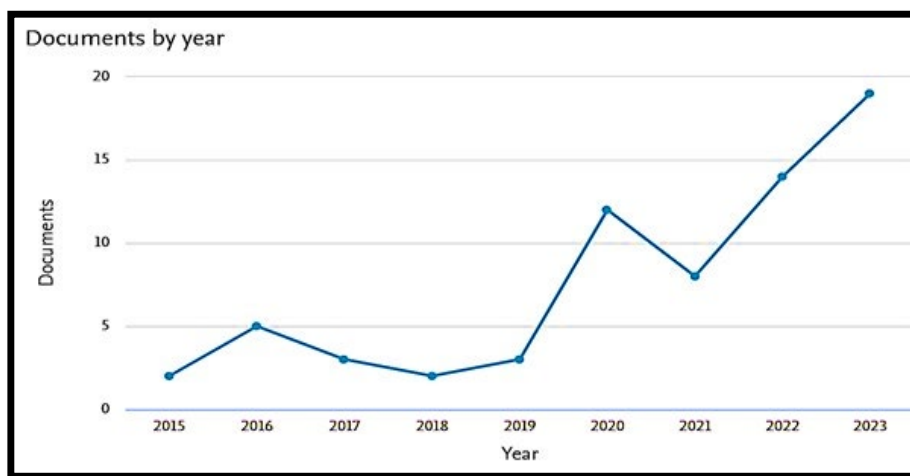


Fig. 3: Annual publication trend from 2015-2023 (Scopus database)

Strategy and the Environment and Corporate Social Responsibility and Environmental Management hold the second place, each contributing 5 articles. Following closely behind, the journal Benchmarking secures the third place with 3 articles. The rest of the journals contribute less than 3 articles.

Table 2 presents the top 10 countries of scientific production in the field of GHRM and sustainable development. Malaysia and China come out as the top-producing nations with 13 documents followed

closely by India with 11 documents. The rest of the countries contribute less than 10 articles. From Table 2, it is clear that developing nations have contributed more to the GHRM and sustainable development literature. By observing the Sustainable Development score-2023 of the nations, it can be assumed that nations with low ranks are striving to come to top positions by conducting more research on sustainable development areas. It must be noted that France and Poland having secured 6th and 8th position in the

Table 1: Top active journals (Authors analysis)

Journals	Number of articles	Publishers	Citations	H-index
Journal of Cleaner Production	22	Elsevier	2939	19
Business strategy and the environment	5	Wiley-Blackwell	400	4
Corporate social responsibility and environmental management	5	Wiley-Blackwell	358	4
Benchmarking	3	Emerald	192	3
Entrepreneurship and sustainability issues	2	Entrepreneurship and Sustainability Center	52	2
International journal of manpower	2	Emerald	113	2
International journal of organizational analysis	2	Emerald	151	2
Journal of Sustainable Tourism	2	Taylor & Francis	93	2
Baltic journal of management	1	Emerald	4	1
Business Strategy and development	1	Wiley-Blackwell	15	1

Table 2: Top producing countries (Authors analysis)

Countries	Number of articles	Citations	Type	Sustainable Development Score - 2023
Malaysia	13	795	Developing	78
China	13	656	Developing	63
India	11	681	Developing	112
United Kingdom	9	878	Developed	11
Pakistan	8	316	Developing	128
Brazil	7	1119	Developing	50
France	7	522	Developed	6
United States	6	477	Developed	39
Palestine	5	958	Developing	-
Poland	4	95	Developing	9

Table 3: Highly cited countries (Authors analysis)

Countries	Citations	Number of articles
Brazil	1119	7
Palestine	958	5
United Kingdom	878	9
Malaysia	795	13
India	681	11
China	656	12
France	522	7
United States	477	6
Indonesia	462	3
Pakistan	316	8

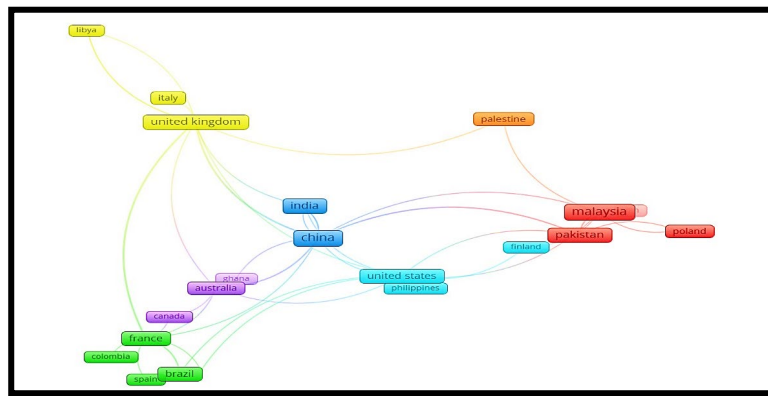


Fig. 4: Collaborative research relationship among countries (Authors analysis)

Table 4: Top 10 affiliations (Authors analysis)

Affiliations	Countries	Number of articles
An-Najah National University	Palestine	6
Sant'anna School of Advanced Studies	Italy	6
Xi'an Jiaotong University	China	6
Universiti Teknologi Malaysia	Malaysia	5
Curtin University	Australia	4
National Institute of Industrial Engineering	India	4
University of Malaysia Terengganu	Malaysia	4
University of the Punjab	Pakistan	4
Zhejiang Gongshang University	China	4

sustainable development score are not in the top 5 producing nations. But India and Pakistan with 112th and 128th positions in the sustainable development scores are in the top 5 producing nations.

Table 3 lists the top-cited nations. Brazil stands first in terms of citations with 1119 global citations although it does not come under the top 5 producing nations. This indicates Brazil's potential to emerge as the top-producing nation soon. Palestine ranks second with 958 citations with just 5 documents. The UK comes as the third top-cited nation with 878 citations. Malaysia being the top-producing nation stands as a fourth top-cited nation with 795 citations. India being the third highest producing nation takes the fifth place with 681 citations. Countries Co-authorship network shows the geographical distribution and collaborative research relationship among countries in the field of green HRM and sustainable development. Based on frequent collaborations, Countries are grouped into 7 clusters. Each country is

observed to have many international collaborations. China, the United Kingdom, the United States, and India show maximum collaborations with countries from different clusters. These collaborations show the interconnected nature of research in GHRM and Sustainable development with strong regional as well as cross-continental collaborations.

Table 4 lists the top 10 universities that have published on "GHRM" and "sustainable development" throughout the world from 2015 to 2023. An-najah National University, Santanna School of Advanced Studies, and Xi'an Jiaotong University are the top contributing universities. It is to be noted that the first three main contributing universities are from developing nations.

Sankey diagram which uses nodes and links to illustrate the movement of values from one stage to another is an effective tool for data visualization. Relevant elements are shown in the Sankey diagram utilizing a range of colors like red, yellow, blue, green,

and orange. The length of the rectangle indicates the relationship between numerous factors like nations, sources, significant authors, etc. The broader the rectangle, there are more relationships between the components (Kumar *et al.*, 2021). Three field plot in the Sankey diagram depicts the relationship among any of the 3 main characteristics like sources, authors, countries, affiliations, keywords, etc. It helps to identify the specific research interests of universities of different countries. It is important to note the height of the box and the thickness of connecting lines. A higher box implies more contribution and thicker connecting lines imply more number of works. In Fig. 5, A three-field plot with keywords on the left side, Countries in the middle, and universities on the right side was plotted. From the figure, it is clear that Malaysia had the most affiliations followed by India. Universiti Teknologi Malaysia stands as the top contributing institution of Malaysia. Following Malaysia, India stands as the second high contributing nation and The National Institute of Industrial Engineering stands as the top contributing institution in India. Regarding the keywords, “green human resource management” stands first with numerous connections to different countries. The keyword Sustainable development is connected to Malaysia, India, Brazil, China, Pakistan, United Kingdom, France, Italy, Saudi Arabia, USA and Australia. The keywords Green human resource management, sustainable development, environmental performance, environmental sustainability, sustainability, GHRM, and green behavior are found to have the most

connections with many countries. Countries like Malaysia, India, China, Brazil, and Pakistan are connected to various research keywords.

RQ3: Prominent themes and their evolution Thematic analysis

The thematic analysis develops themes using author keyword clusters and their connections between them. Density and centrality are features that define these topics. The centrality is depicted on the horizontal axis while density is represented on the vertical axis. These features help to identify the most significant topics. It also explains the current status of a particular theme and its future potential directions. The size of the cluster in the thematic map infers the frequency of occurrence. The position of the cluster tells about its prominence. Fig. 6 represents the thematic map of green HRM and sustainable development. It is equally divided into 4 quadrants. Quadrant 1, positioned in the upper right corner, illustrates the most predominant theme characterized by high centrality and density. Quadrant 2, located in the upper left corner, portrays more specialized themes with high density and low centrality. Quadrant 3, situated in the lower left corner, represents emerging or declining themes with low centrality and low density, while Quadrant 4 in the lower right corner represents basic themes.

The clusters’ sustainable development and human resources are seen as motor themes. The sustainable development cluster represents the studies that focus on the impact of GHRM on sustainability (Joshi

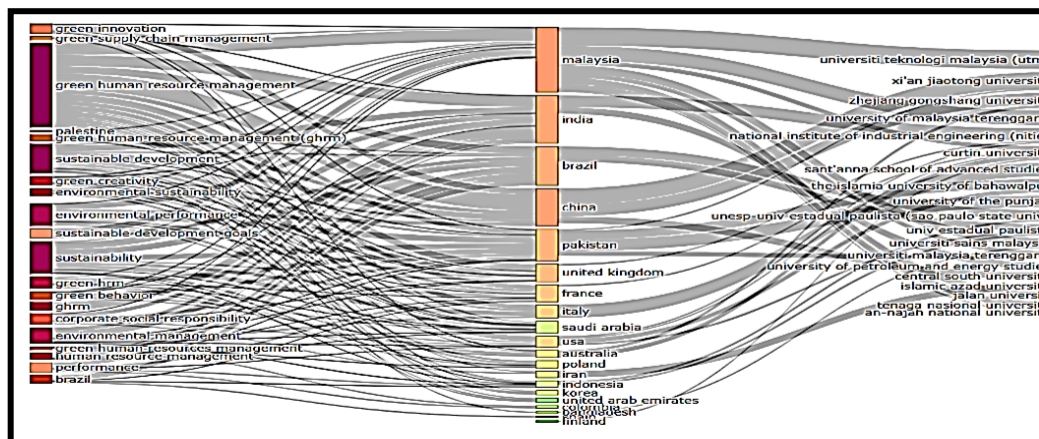


Fig. 5: Three field plot (Authors analysis)

et al., 2023; Mousa and Othman, 2020; Paillé *et al.*, 2020) The cluster human resource mainly represents studies that focus on GHRM and green creativity in the hospitality industry (Farooq *et al.*, 2021). The cluster corporate social responsibility lies in between Niche and motor themes. This cluster represents studies that talk about the link between Corporate social responsibility, GHRM, and Sustainable performance (Tanveer *et al.*, 2023). The cluster Supply chain management lies in between basic and motor themes. This cluster focuses on studies that talk about the combined effect of GHRM and Green Supply Chain Management (GSCM) on organizational sustainable performance (Jabbour and de Sousa Jabbour, 2016; Teixeira *et al.*, 2016). The cluster India is found in quadrant 3. To confirm whether India is in an emerging or declining state, the bibliometric data was analyzed, and found that India stands as one of the top-producing countries in this domain which confirms it as an emerging theme. The cluster Industrial research represents studies conducted in the manufacturing sector (Masri and Jaaron, 2017; Piwowar-Sulej, 2022). Cluster Planning represents studies that use Structural equation modeling in their study (Gholami *et al.*, 2016; Jabbour *et al.*, 2015).

Evolution of themes

To understand the evolution of keywords on GHRM and sustainable development in recent years, thematic evolution maps were visualized. Fig. 7,

represents the thematic evolution of keywords in the period between 2015 and 2019. Fig. 8, represents the thematic evolution of keywords in the period 2020-2023. Between the period 2015-2019, there are only 3 keyword clusters which implies that the topic was in the budding stage. But there are 7 keyword clusters in the period of 2020-2023. Thus, Figs. 7, and 8 clearly show that research on GHRM and sustainable development has greatly increased in the last few years. In Fig. 7, the sustainable development keyword cluster is found in the midline between motor themes and basic themes whereas in Fig. 8, it is seen as a motor theme with high centrality and high density. So, it is evident from the thematic maps that sustainable development has been gaining more attention in recent years. In Fig. 7, Manufacture is seen as a niche theme which implies that initially green hrM and sustainable development studies were adopted mainly in the manufacturing sector. It must be noted that Organizational sustainable performance is observed as the emerging keyword cluster in the period between 2020-2023 and also Corporate social responsibility is observed as a niche theme. Similarly, Supply chain management is also seen as an emerging theme in the period between 2020-2023. However, the initial efforts to combine GHRM and GSCM to achieve sustainability happened between 2015 and 2019 (Jabbour and de Sousa Jabbour, 2016; Zaid *et al.*, 2018).

The keyword co-occurrence network depicts

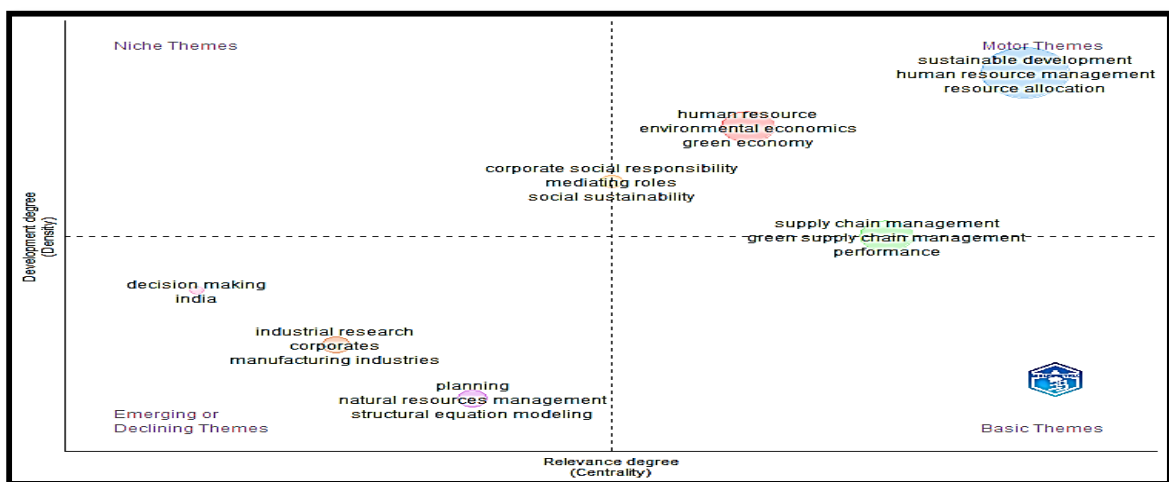


Fig. 6: Thematic analysis (Authors analysis)

the evolution of the keywords and themes around GHRM and sustainable development over the years. The keyword “GHRM” is seen as the central prominent keyword which is closely linked with “environmental performance” and “sustainability”. This implies a strong association between “green hr” and “sustainability”. Keywords in blue indicate older research while keywords in yellow show emerging research interests. Thus, green creativity,

green innovation, and green behavior are observed as emerging research areas. Thus, it is visible that earlier studies focused on the integration of GHRM and GSCM (Jabbour and de Sousa Jabbour, 2016; Teixeira et al., 2016) whereas recent studies examine GHRM’s role in promoting behavioral changes in employees (Farooq et al., 2021) These findings are in convergence with and review (Khan and Muktar, 2020) transitioning from a primary emphasis on

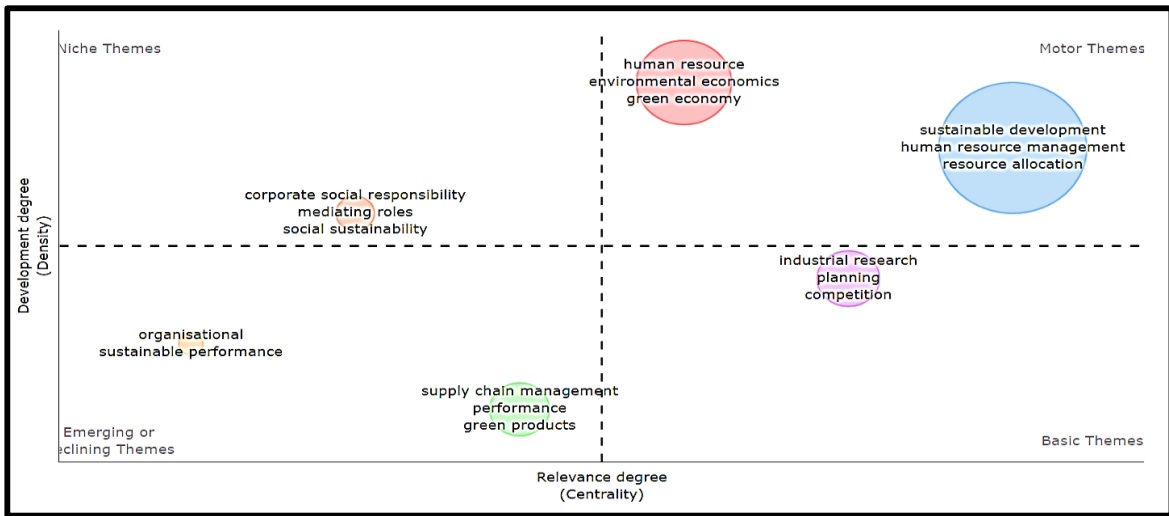


Fig. 7: Thematic evolution (2015-2019) (Authors analysis)

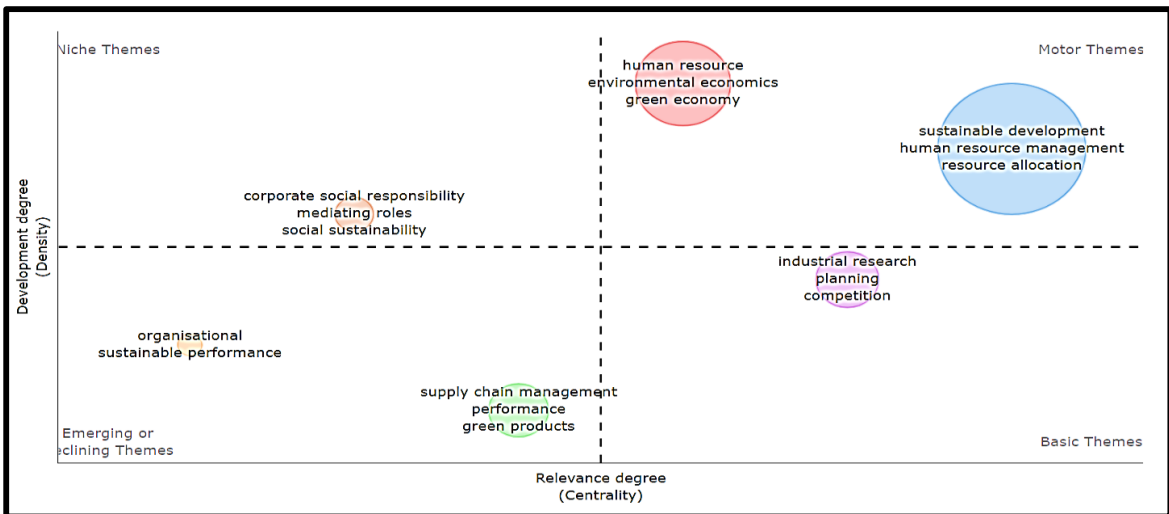


Fig. 8: Thematic evolution (2020-2023) (Authors analysis)

organizational-level environmental performance to a renewed focus on giving importance to employees.

RQ4: Prominent Authors and their Connections

The evaluation of a researcher's contribution not only includes mere paper count but also includes the extent to which it helps fellow researchers. Table 5 lists the most relevant authors in the field of GHRM and sustainable development. Jabbour CJC emerges as the most relevant author having published 6 articles from the year 2015. Among his 6 articles, 4 have gained more than 200 citations. De Sousa Jabbour ABL stands second with a remarkable citation count of 905 for his 4 articles. Latan stands third with a notable citation count of 462 for his 3

articles. Zaid AA occupies the fourth place with a citation count of 392 for his 3 articles. The rest of the authors have contributed less than 3 articles in the field of GHRM and sustainable development. The h-index acts as a prevalent metric for recognizing proficient researchers in a discipline. It demonstrates the collective impact of research work by considering both the number of citations and the number of article downloads at the same time. It is observed that Jabbour CJC has made a significant contribution and has secured an h-index at 6. The g-index slightly varies from the h-index by giving more weightage to the highly cited articles.

A historical direct citation network or historiograph uses the histplot function to create maps of the most

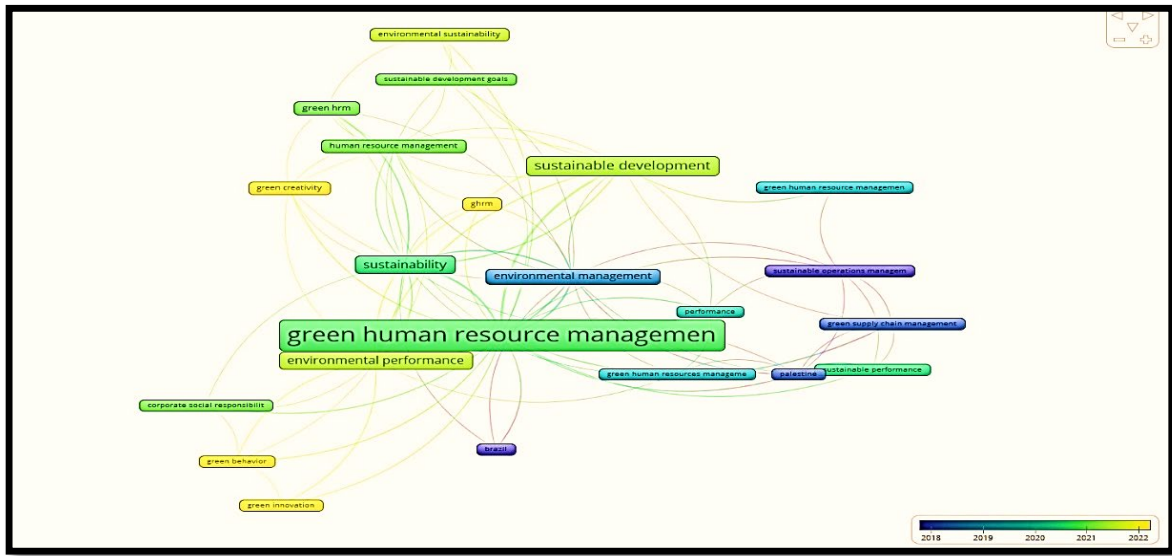


Fig. 9: Recurring keywords on GHRM and sustainable development scholarship (Authors analysis)

Table 5: Top relevant authors (Authors analysis)

Authors	Total production	Total Citations	h-index	g-index
Jabbour CJC	6	1440	6	6
De Sousa Jabbour ABL	4	906	3	4
Latan H	3	462	2	3
Zaid AA	3	392	2	3
Agrawal W	2	6	2	2
Bombiak E	2	52	2	2
Daddi T	2	63	2	2
HO TH	2	26	2	2
Iqbal Q	2	38	2	2
Iraldo F	2	63	2	2

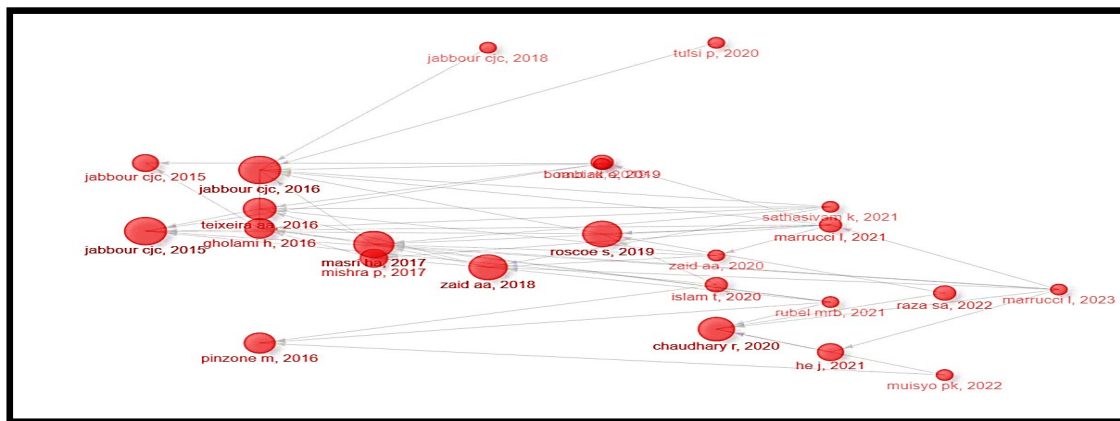


Fig. 10: Historical direct citation network (Authors analysis)

pertinent citations of the given Bibliometric data (Aria and Cuccurullo, 2017). Historiography forms intellectual connections in chronological order. Thus, it helps the academicians to discover the significant work while chronologically tracking its evolution period. By observing Fig. 10, It is visible that Jabbour CJC has made the first step in contributing to the literature on green hrm and sustainable development, starting with his publications, Green Product Development and Performance of Brazilian Firms: measuring the Role of Human and Technical aspects (Jabbour et al., 2015) and Environmental training and environmental management maturity of Brazilian companies with ISO14001: Empirical evidence (Jabbour, 2015). Again, in the very next year, he made a notable contribution, “Green Human Resource Management and Green Supply Chain Management: Linking Two Emerging Agendas” which is highly cited among other authors (Jabbour and de Sousa Jabbour, 2016). Other Notable Authors whose publications got high citations include (Roscoe et al., 2019), (Masri and Jaaron, 2017), (Zaid et al., 2018). Thus, Jabbour CJC and De Sousa Jabbour have made significant contributions from 2015-2018.

RQ 5: Prominent works on GHRM and sustainable development literature

DISCUSSION

Following the UN endorsement of SDGs in 2015, both scholars and business practitioners have shifted their focus to the concept of “sustainable

development” and other green practices. So, this study was conducted to find the research landscape of “GHRM” and “sustainable development”. Although the concept of “GHRM” has flourished in recent years. The studies about “green HRM” and “sustainable development” are still in the infancy stage which is evident from the current study. To understand the research landscape, 5 research questions were formulated. Research questions were answered through descriptive and network analyses. For answering RQ1, descriptive statistics was performed to find the distributions of articles across various subjects and also the yearly publication trend. Fig. 2 shows that the concept of “GHRM” and “sustainable development” is studied across 8 distinct subject areas. This shows the multi-dimensional nature of the topic and its importance in incorporating it in all domains. In Fig. 3, it must be noted that, out of 68 total documents, 53 publications were made after 2020. Although the first five years demonstrated steady growth, a significant increase in publications has been observed since 2020. This surge can be attributed to the profound impact of the COVID-19 pandemic, which has affected social, financial, and ecological aspects of our lives, highlighting the importance of sustainable practices (Nundy et al., 2021). Additionally, global events such as COP26, the High-Level Political Forum on Sustainable Development, and Stockholm+50 have heightened awareness about the importance of sustainable development, contributing to the recent rise in publications. Previous studies also suggest that the

Table 6: Prominent works on GHRM and sustainable development

Author	Summary	Year	Citations	Future research directions
(Jabbour and de Sousa Jabbour, 2016)	This study proposes a framework integrating GHRM and GSCM for attaining organizational sustainable performance.	2016	443	Future studies can check the validity of the framework through qualitative\ quantitative methods.
(Zaid et al., 2018)	The study aims to provide empirical evidence on the relationship between GHRM, GSCM, and sustainable performance and highlights the joint impact of GSCM and GHRM on sustainable outcomes.	2018	387	The study is limited to the Palestinian context. Thus it can be replicated in other developing countries and sectors to check whether the findings can be generalized.
(Roscoe et al., 2019)	The study finds 4 key enablers of green organizational culture and explains the impact of pro-environmental HRM practices on the environmental performance of firms.	2019	364	The study can be replicated in other developing countries and sectors to check whether the findings can be generalized.
(Masri and Jaaron, 2017)	The study reveals that organizations with effective environmental management systems have implemented GHRM practices. It also underscores the importance of these practices in enhancing environmental performance within the Palestinian context.	2017	303	The study can be replicated in other developing countries to check whether the findings can be generalized.
(Mousa and Othman, 2020)	The study highlights how implementing GHRM practices like green hiring, green training and development, and green performance management can improve sustainability in healthcare organizations.	2020	264	Future researchers can apply the proposed framework in different environments \ sectors to better understand the role of GHRM practices on sustainable performance.
(Teixeira et al., 2016)	This Brazilian study indirectly underscores the significance of integrating GHRM and GSCM by providing empirical evidence on the relationship between green training and GSCM.	2016	234	This study is limited to the Brazilian context. Thus future studies can be carried out in developed\ developing countries to check the generalisability of findings.
(Jabbour et al., 2015a)	The study confirmed the significance of technical aspects and emphasized the importance of understanding the relationship between human factors and green product development in Brazilian companies.	2015	227	Future studies can analyze the relationship between human factors and green product development to better understand the significance of human factors.
(Pinzone et al., 2016)	This research delves into the influence of GHRM practices on the collective engagement of employees in environmental protection within healthcare organizations and it also examines the mediating role of collective commitment.	2016	226	The current study uses a cross-sectional design. To establish causality, future studies can adopt longitudinal research.
(Chaudhary, 2019)	The cross-sectional study found that the effectiveness of GHRM in fostering organizational identification and subsequently promoting green behaviors is likely to be consistent among all employees, irrespective of their environmental values and gender.	2020	219	Future researchers can replicate the study using a time-lagged or experimental design.
(Mishra, 2017)	The study makes it clear that the implementation of GHRM practices is still in the development stage in India and also emphasizes the importance of top management and mutual learning for attaining organizational sustainability	2017	148	Future researchers can study the impact of specific GHRM practices on organizational sustainability.

rise in publications over time may be attributed to organizational regulations on sustainability and green standards. (Benevene and Buonomo, 2020). About RQ2, the Journal of Cleaner Production is seen as the most promising source since the early stage. The first article published on this topic was from the Journal of Cleaner Production and it has contributed over 22 articles till 2023. The top 4 active journals account for 52% of total publications. According to the findings of (Khan and Mukthar, 2020), the study on green HRM scholarship was mainly carried out in the western regions of the world. As per the findings of (Zhu and Hua, 2016), the top-producing nations in sustainable development research were the US, the UK, and the Netherlands. In contrast to the above two studies, this study finds that developing nations like Malaysia, China, and India have done a significant number of research on GHRM and Sustainable development scholarship. This indicates a need to carry out extensive research on GHRM and sustainable development. This shows the studies were mainly carried out in the Asian continent. This is in agreement with the findings of a previous study by Amrutha and Geetha (2020), which shows that GHRM scholarship was mainly carried out in Asia and Europe. At COP26, Malaysia committed to net zero emissions by 2050. The Malaysian Investment Development Authority (MIDA) supports this goal through the MIDA ESG initiative, offering incentives for decarbonization and circular economy activities, and positioning Malaysia as a leader in GHRM and sustainable development. China, the largest greenhouse gas emitter, committed to carbon neutrality by signing the Paris Agreement. With a 25% annual increase in renewable energy consumption over the past five years, China's commitment to sustainability has made it the second top-producing nation in this field. India's environmental practices have significant global implications. Extensive research on sustainable practices is essential to address these challenges. As a signatory to the Paris Agreement, India is committed to reducing greenhouse gas emissions and promoting sustainable development. National policies like the National Action Plan on Climate Change (NAPCC) further underscore this commitment, positioning India as the third top-producing nation in sustainable development. Brazil faces significant environmental challenges like deforestation, pollution, water scarcity, and biodiversity loss. International pressure

to address Amazon deforestation has spurred impactful research focused on sustainability solutions, contributing to Brazil's high citation rates. While the Palestinian economy is classified as a middle-income developing country based on its economic performance measures, structural barriers that are typical of Least Developed Countries (LDCs) prevent the country from developing further (United Nations, 2024). But still, Palestine emerges as the second top highly cited nation. Both Brazilian and Palestinian researchers frequently publish in the high-impact journal, Journal of Cleaner Production contributing to their high citation rates. In Brazil, agencies like CNPq (National Council for Scientific and Technological Development) and FAPESP The Sao Paulo State Research Foundation support scientific development through grants and scholarships resulting in high-impact works (Jabbour et al., 2015; Teixeira et al., 2016). This may be one of the reasons for impactful research works. Fig. 4 shows the varied research interests of researchers of different universities from different countries on green HRM and sustainable development. About RQ3, The thematic analysis helped to find the motor themes of research on GHRM. It underscores the interconnectedness of green HRM, sustainable development, and related themes, showing their growing significance in contemporary research and practice. Figs. 7 and 8 show the immense growth in the literature of GHRM and sustainable development. While Fig. 7 Thematic Evolution (2015-2019) has only 3 keyword clusters, Fig. 8 Thematic Evolution (2020-2023) shows 6 keyword clusters. In Fig. 8, Organisational Sustainable performance is seen as an emerging area between 2020-2023 (Alenzi et al., 2023; Mousa and Othman, 2020). Recent studies relate GHRM and corporate social responsibility to achieve organizational sustainable performance (Sabokro et al., 2021; Bansal and Agrawal, 2022). Fig. 9 clearly shows the evolution of keywords and themes on the concept. Thus, green creativity, green behavior, and green innovation are observed as the recent trending keywords. A case study conducted in China provides empirical evidence on how stakeholders influence the adoption of green process and product innovation strategies in manufacturing firms. This shows the empirical outcome of the emerging green innovation strategy (Guoyou et al., 2011). Similarly, The case study conducted in Poland provides insights into how the

emerging theme, of green behavior, influences the adoption of bike-sharing systems, a GHRM practice (Macioszek *et al.*, 2020). These case studies show the manifestation of the emerging themes in practice. About RQ4, From Table 5, it can be seen that the top 3 prolific authors are Jabbour CJC and De Sousa Jabbour and Latan H. From Fig. 10, It is visible that the most notable Authors are Jabbour and De Sousa Jabbour. They have made noteworthy contributions in the initial stage of GHRM and sustainable development literature (2015-2018). Both authors are from Brazil which has resulted in Brazil being the highly cited country. About RQ5, An examination of the top 10 most cited articles in the literature provides insights into their research contributions to the fields of GHRM and sustainable development (Table 6). This study additionally functions as a reference for management Professionals seeking to identify valuable practical insights on the topic by highlighting important contributors such as articles, authors, sources, countries, and affiliations. It assists researchers in pinpointing the most impactful articles that have significantly contributed to this domain. Consequently, individuals can readily focus on the aforementioned resources to gain a comprehensive understanding of the subject matter.

Limitations

Similar to other research, this study has its limitations. The results were derived using biblioshiny with R programming, which does not seamlessly integrate data from diverse databases. Therefore, this study relied exclusively on articles sourced from the Scopus database, limiting the generalizability of the findings. Future studies could broaden their scope by considering alternative databases such as Web of Science (WoS) or Google Scholar. Additionally, future researchers could conduct bibliographic analyses on GHRM and sustainable development within specific industries like service and manufacturing, rather than focusing solely on “Business, Management, and Accounting” disciplines. Given the multidimensional nature of sustainable development, studies in other disciplines would be beneficial. Since the field is still emerging, conducting Bibliometric studies on this topic every decade could provide insights into its growth and impact. Despite these limitations, the study has underscored the importance of GHRM practices in achieving organizational sustainable development.

CONCLUSION

Green Human Resource Management lacks a universal definition; older studies link it to environmental management, while recent studies view it as a goal that fosters attitudinal changes to enhance organizational performance. Therefore, proposing a universal definition for GHRM is necessary. This study highlights that research on GHRM and sustainable development predominantly occurs in Asia and developing countries. Future studies could expand to developed countries and various industries, fostering further growth in the field. Policymakers can allocate funds for research on Green HRM, particularly in developed countries and diverse industries. This can help build a robust body of knowledge and address existing gaps. Further, they can introduce incentives, such as tax benefits or grants, for organizations that implement effective GHRM practices. This can motivate companies to adopt and innovate in GHRM. Future studies could propose frameworks for achieving organizational sustainable performance through GHRM, advancing the field. Corporate Social Responsibility (CSR) has become a niche theme since 2020; therefore, future research could explore how CSR facilitates Green HRM and contributes to organizational sustainable performance. Additionally, big data analytics are recognized for promoting green innovation and achieving environmental performance (Waqas *et al.*, 2021), suggesting avenues for further investigation into their role. Future studies could explore related variables and conduct longitudinal research to understand the evolving relationship. Embracing GHRM principles and fostering a culture of environmental responsibility can empower organizations to implement sustainable business practices and contribute to a sustainable future.

AUTHOR CONTRIBUTIONS

S. Pooja carried out the idea development, methodology, software, review of literature, and manuscript preparation. J. Bhavani corrected data, reviewed, and edited it, checked software, and validated it.

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CONFLICT OF INTEREST

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

PUBLISHER'S NOTE

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ABBREVIATIONS

AMO	Ability Motivation Opportunities
CDP	Carbon Disclosure Project
COP26	26th Conference Of the Parties (United Nations Climate Change Conference)
CNPq	National Council for Scientific and Technological Development
CSR	Corporate Social Responsibility
CSV	Comma-Separated Values
FAPESP	The Sao Paulo State Research Foundation
GHRM	Green Human Resource Management
GSCM	Green Supply Chain Management
HR	Human Resource
HRM	Human Resource Management
ISO	International Organisation For Standardisation
LDC	Least Developed Countries
MIDA	Malaysian Investment Development Authority
NAPCC	National Action Plan on Climate Change
PRISMA	Preferred Reporting Items For Systematic Reviews And Meta-Analyses
RQ	Research Question
SASB	Sustainability Accounting Standards Board
SCM	Supply Chain Management
SDG	Sustainable Development Goals

UK	United Kingdom
UNGC	United Nations Global Compact
US	United States
WoS	Web of Science

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CONTENTS

Volume 10, Number 1, Winter 2025
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1 - 22

Reverse osmosis for the treatment of well water and wastewater for reuse

A. Melendez-Rivera, J.C. Musa-Wasil, D.K. Almestica-Martinez, K.J. Malave-Llamas, (USA)

23 - 38

On the master plan conformance with urban reality: A comparative assessment

M. Jahanbani, E. Lashkari, (CANADA/IRAN)

39 - 56

Structural equation modeling of collective decision-making's impact on group cohesion

S.M. Mirbagheri, A. Rafiei Atani, M.R. Parsanejad, R. Jafari, (IRAN)

57 - 70

Integrating human resource management in urban workforce development: A focus on salary increments

L. Yu, A.R. Santos, (CHINA/PHILIPPINES)

71 - 84

Exploring individual and organizational contributors to workplace deviant behavior

D. Daryono, R.S. Gunawan, U. Udin, (INDONESIA)

85 - 104

On the concept of Urban Mutations: Urban research bibliography with an objective approach

Z. Bendebache ; A. Khiari; I. Maanseri, (ALGERIA)

105 - 120

The influence of pandemics in neighborhoods' public realms: Experts' point of view in light of social capital

A. Asadpour, H. Nikounam Nezami, (IRAN)

121 - 134

Statistical analysis based on a two-staged SEM-SVM approach for environmental noise annoyance prediction and identification of influencing factors

M.U. Rehman, M. Kamal, S.K. Tiwari, (SAUDI ARABIA/INDIA)

135 - 148

A closer look at the work behavior of Gen Z in Micro, Small, and Medium Enterprises of developing countries

I. Astuty, R. J. Astuti, S. M. Mahmud, V. Widodo, (INDONESIA)

149 - 162

The mediating effect of job satisfaction in the relationship between wages, appreciation, recognition, and promotion on employee performance

D. Kumar, H. Vasudevan, (IRAN)

163 - 178

Effect of technology application in enhancing the weaknesses of market access, financial resources, and supplier resources on the aluminum industry

M.S. Mohamad Salleh, H. Vasudevan, (MALYSIA)

179 - 198

Bibliometric analysis of research trends in Green Human Resource Management and sustainable development

S.Pooja, J.Bhavani, (INDIA)

