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RULE OF LAW AND ITS EFFECTS ON ECONOMIC GROWTH

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ABSTRACT

It is generally assumed that the rule of law is essential for economic growth. However, it is clearly a multidimensional concept, including a variety of discrete components. Literature has a huge amount of cross-national data claiming to measure the rule of law. Yet even the very best work in the field has not been adequately attentive to the multidimensionality of the rule of law concept. As a governance principle, it ensures the enforcement of equality in a society, in different spheres. Therefore, in a broader sense, it ensures the avoidance of arbitrariness and is interconnected with institutions and economic growth and development. The 2023 Rule of Law Report, including its 27 country chapters, examines developments across all Member States in four key areas for the rule of law: the justice system, the anti-corruption framework, media pluralism and freedom, and other institutional issues related to checks and balances. The World Justice Project developed the World Justice Project Rule of Law Index as a quantitative tool that measures the rule of law in practice. This article's aim is to present the World Justice Project Index for Croatia and other EU countries as a helpful tool for comparative methods with another measurement of the Rule of Law, for instance, the Rule of Law Group/Pillar as apart from the Economic Freedom Index. Additionally, this article aims to present chosen research on the rule of law and institutions and its relation to economic indicators and economic growth and development. The article will present theoretical and empirical secondary data on the relationship between institutions, the rule of law, governance, and economic growth.

KEY WORDS

rule of law, WJP, economic growth, governance

CLASSIFICATION

JEL: H11, K00, O43, P48

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INTRODUCTION

The relationship between the rule of law and economic growth is of great interest not only in the academic community but also in the public sector and state governance. Considering the complexity of the rule of law's scope, its unique definition is impossible. According to the political philosophy perspective given by Britannica, the rule of law is defined as the mechanismp, process, institution, practice, or norm focused on the equality of all citizens before the law and enabling no arbitrary form of government.

In other words, the rule of law is the mechanism, process, institution, practice, or norm that supports the equality of all citizens before the law, secures no arbitrary form of government, and, in a more general sense, prevents the arbitrary use of power [1]. Although very similar, a bit broader definition was given by the United Nations: '(…) the rule of law is a principle of governance in which all persons, institutions, and entities, public and private, including the State itself, are accountable to laws that are publicly promulgated, equally enforced and independently adjudicated, and which are consistent with international human rights norms and standards. It requires measures to ensure adherence to the principles of supremacy of the law, equality before the law, accountability to the law, fairness in the application of the law, separation of powers, participation in decision-making, legal certainty, avoidance of arbitrariness, and procedural and legal transparency' [2]. The interconnectedness of the rule of law and institutions is undeniable, as well as the impact on economic growth and (economic) development. The importance of the rule of law and institutions is even part of a Sustainable Development Goals Agenda set by the United Nations, which is visible in the 16th Goal, 'Peace, Justice, and Strong Institutions' [3].

According to the view of economists, the wealth of the economic system depends on institutions, not on individuals, and an efficient institutional structure can solve problems related to market uncertainty and asymmetric information, create positive heterogeneity, and enable efficient distribution of resources. The institutional structure includes significant factors related to the rule of law, control of corruption, freedom of expression, political stability, quality of bureaucracy, and guarantee of property rights [4]. Taking into account Southeast Europe, as calculated and stated by Nedanovski and Shapkova Kocevska, the regression model analysis results confirmed that stronger adherence to the rule of law stimulates economic growth [5]. Although the mentioned region belongs to the less developed one compared to some of the other EU regions, the positive impact of the rule of law implementation was still confirmed.

Bufford [6] states that the rule of law is an indispensable foundation for a market economy and provides an essential instrument for creating and preserving wealth, economic security, and well-being, as well as improving the quality of life. Separate legal structures are required to support a market economy and to provide for its effective operation. These structures must operate at the legislative, administrative, and judicial levels. A country will always be poor without adequate legal structures to support economic activity. The Rule of Law requirements for a market economy differ substantially from those for other types of social needs [6].

Addink [7] emphasises the differences in the historical roots and traditional perspectives, i.e. common law and continental law, although both systems have a focus on the rule of law. The tradition of common law is based more on limiting the powers of the state, while the continental tradition is not only on limiting but also on empowering the government [7]. Since governance appears as a way of making laws, Ciacchi and von der Pfordten [8] mention four specific relations between governance and law: governance as law, governance in law, governance through law and governance against the law. According to some definitions, governance is exercising authority or control to manage a country's affairs and resources [9]. Besides,

governance is a sophisticated process of interactions between structures, traditions, functions, and procedures defined by accountability, transparency, and participatory principles [10].

Over time, the fundamental basis of governance has evolved, and it is a crucial element in leadership and implementation. Governance is increasingly being identified as one of the most critical issues to economic growth in most emerging countries, and "institutions are the rules of the game in a society or humanly devised constraints that shape human interaction and structure incentives in human exchange, shape actions of individuals to maximise the utility of principals" [11; p.16].

Thriving market economies depend on strong states that secure private property rights and their voluntary transfer. However, the strength of the state can be its greatest weakness. If it is strong enough to secure private property rights, it could also be strong enough to attenuate them or even to expropriate its citizens. A simple promise to honour private property rights in the future will not be credible: the citizens know that, after they have invested, the state is incentivised not to keep its promises and to hold citizens up. An independent judiciary could make all actors better off in such a setting. If it can make the representatives of the state stick to their promises, additional (physical and human capital) investment could lead to higher income and growth, as well as higher tax receipts for the state [12].

The article aims to present previous research on the relationship between economic indicators and the rule of law. Furthermore, based on the presented results, the work aims to show that the rule of law forms the basis for economic development. The article discusses previous theoretical and empirical research related to the connection between institutions and the rule of law, as well as research on the connection between governance and its impact on economic growth. In a perspective where factors such as corruption prevention and freedom of expression are present, the institutional structure significantly affects economic development. Furthermore, the article presents the features of the rule of law. It depicts the rule of law index according to the World of Justice Project (WJP), emphasising the Rule of Law Justice index according to income for high-income countries. Furthermore, the Rule of Law Justice index for Croatia for the year 2023 is analysed.

LITERATURE REVIEW

There are several studies on the connection between the institutional structure and its characteristics and the economic performance of countries. In the study that Kaufmann, Krayy, and Zoido-Lobaton [13] conducted on 150 countries, they found an evident cause-and-effect relationship between the rule of law and income per capita and infant mortality rate. Furthermore, the per capita gap may be three times greater in countries that do implement the rule of law principle compared to countries that do not implement it. In his research, the Nobel-winning economies announced that he believes that economic growth is not possible without the requirements of the rule of law and further argues that in order to ensure long-term economic growth, especially in a dictatorial regime, development in the law of rule issues is needed. North and Thomas [14] believe that the lack of property rights protection prevents capital investments that would help economic growth.

Furthermore, Knack and Keefer [15] and Haal and Jones [16] claim a positive relationship between property rights and economic growth. Protecting property rights and taking them under the state guarantee, thus increasing investment demand, affects economic growth positively, as it does in technological and other innovations. Knack believes it is possible to prevent macroeconomic instability precisely in the previously mentioned way [15]. In their study covering the period from 1950-2009, Valerani and Peluso [17] performed a panel data analysis for 181 developed and developing countries. According to the results, institutional quality

positively affects economic development in developed and developing countries. Therefore, it is possible to conclude that social welfare and per capita income increase seriously with an increase in the rule of law in a country [18]. When speaking of the relationship between regulations, quality, prevention of corruption, and economic growth, Ata, Koc, and Akca [19], in their research that covered 30 OECD countries, found positive and statistically meaningful results.

Some studies further define that the positive effect of institutional structure on economic growth is possible only in developed countries. In this respect, Yaprak [20], in his study of 36 middle-income countries, found a negative relationship between components of institutional structure and economic growth. Bienen [21] and Sachs and Warner [22], in their study of African countries, stated that weak growth in Africa is caused by natural causes such as limited access to the sea, abundance of natural resources, and tropical climate, but, furthermore, they concluded that institutions significantly affect economic growth. Helliwell [23] investigated the relationship between democracy and economic development in his study, which included 125 children. In the study, he concluded that there is a positive relationship between democracy and economic growth in high-income countries. Besides the positive effect, however, he claims that democracy has a negative but insignificant effect on growth in low-income countries. Furthermore, in the study published by Alesin and Perroti [24], Alesina and Rodik [25], Alesina et al. [26], Chong and Calderon [27] and Chang [28], results show that the institutional structure is not as effective as it is in developed countries [18].

Since governance appears as a way of making laws, as defined in the introduction, and a sort of implementation, the literature review of governance importance is being presented as well. Mira and Hammadache [29] study the relationship between the implementation capacity of governance principles, as defined by the World Bank, and the economic performance of 45 developing countries. They use several regression model estimations – similar to Samarasinghe [30] – on the dependent variables GDP growth rate and GDP per capita, along with explanatory variables such as commodity prices, risk perception indexes, and economic growth rates of dominant developed countries. Their findings indicate that given the broad concept of good governance, it is rather difficult to assume a positive correlation between governance and growth, let alone generalise such findings regarding emerging market (E.M.) economies [31]. Nevertheless, Mira and Hammadache [29] find that four of the six variables have a positive correlation with GDP growth; however, only two of these variables are significant: government effectiveness, political stability and reduction of violence [32].

The novel literature on institutions and long-run growth tests similar propositions since either the conception of institutions or the proxy for them is the extent of property rights protection (e.g. [33]). In an interesting extension, Acemoglu and Johnson [34] find that the effects of property rights on growth, investment, and financial development trump the effects of institutions ensuring the integrity of contracts. In addition to the focus on long-run growth, the property rights literature variants have also considered alternative dependent variables, including productivity [16] and investment in fixed assets [35, 36]. Even though the function of governance in economic development has been understood since the 18th century, economic theories have overlooked the significance of governance in production and economic development. However, in today's world, governance has become a major element of whatever economic system has been formed [11]. Governance is a sub-component of an institution that covers all aspects of behaviour and social network, including political, economic, and legal aspects [12]. Strong governance boosts individual and organisational productivity by utilising their resources efficiently in production. Economic actors are more involved in resource reallocations when governance is poor, limiting free market rather than productive activities. Because strong governance lowers company expenses, it promotes the creation of markets in which agents can benefit from each other. It fosters an atmosphere in which people and physical

capital are prioritised. Strong governance minimises macroeconomic instability, uncertainty, and negative externalities. This improves economic efficiency by allowing for more efficient resource allocation. Information for enterprises and consumers to respond rationally and foster free market competition is governance quality. These factors contribute to economic growth [37].

Among recent studies, it is important to mention the connection of digital development to the European economy and society. According to classical and neoclassical economics, the main drivers of growth are technological progress and innovation [38-42]. Economic growth can only be achieved through the development of human capital and the increased integration of digital technology. The integration and use of digital technology are thoroughly linked to human capital development [43, 44]. Therefore, the focus should be on maximising learning opportunities, research, exploration, and development activities at both government and enterprise levels. A framework for digital progress should be developed at the state level and by all companies as a helpful structuring tool to save resources [44]. Management's attention to digitalisation and its ability to gather information from inside and outside the company determine digital transformation's success [45]. The state's responsibility cannot be bypassed to facilitate digitisation efforts. It is responsible for developing the proper framework to ensure that it can be applied in the business sector efficiently [46]. Kovacs et al. [47] conducted an analysis focused on the Member States that joined the EU during the Eastern European enlargements. The study examined the individual indicators of the integration of digital inclusion as widespread as possible. It showed that the performance of all individual indicators is typically below the EU average, while the average catching-up rate is not encouraging. The authors conclude that the state should support digital development through various tendering procedures, which is also unsatisfactory [47].

The study was conducted on the impact of health capital on economic growth in the Balkan countries over the 2000-2019 period. It included annual data for 10 Balkan countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, North Macedonia, Montenegro, Romania, Serbia, and Turkey).

The researchers used panel autoregressive lag of a pooled mean group to examine the relationship. The results revealed that economic growth responds to short-term and long–term health capital changes. Estimation results indicate a positive relationship between health capital and the economic growth of Balkan countries. According to the results, increased health expenditures stimulate higher economic growth and development. The findings imply the need to formulate policies that assign higher priority to the healthcare sector, which would help sustain future economic growth in Balkan countries [48].

A study concerned with economic and environmental sustainability through trade openness and energy production in Saudi Arabian countries was conducted using annual data from 1970 to 2020. The fully modified ordinary least squares and the dynamic ordinary least squares methods were employed to develop two models, including an economic growth model and an environmental Sustainability or pollution model. The results of the two tests ensured that both expanding trade openness and increasing energy production led to faster economic growth. Nevertheless, the expansion of trade openness and energy production also led to environmental pollution; hence, the increase in energy production did not support sustainable development [49].

Another recent and very interesting analysis of the economic and sustainability priorities in the United Arab Emirates aims to suggest strategies that are more effective in assisting economic growth [50]. The authors use the World Bank data set, which collects various stakeholders' opinions on the UAE development. First, exploratory factor analysis was applied to detect the main groups of development priorities. Second, fuzzy cluster analysis has been conducted to detect the groups of stakeholders with different attitudes towards the importance of extracted groups of priorities. Third, clusters were compared according to demographics, media usage,

and shared prosperity goals. The exploratory factor analysis has extracted the two main groups of development priorities: economic priorities and sustainability priorities. Four clusters have been detected according to the level of motivation when it comes to the economic and sustainability priorities: Cluster 1 (High economic High sustainability), Cluster 2 (High economic– Medium sustainability), Cluster 3 (High economic– Low sustainability) and Cluster 4 (Low economic– Low sustainability). Members of the cluster that prefer a high level of economic and sustainability priorities (Cluster 1) also prefer more diversified economic growth, which provides better employment opportunities and better education and training for young people in the UEA [50].

METHODOLOGY

The 2023 Rule of Law Report, including its 27 country chapters, examines developments across all Member States, both positive and negative, in four key areas for the rule of law: the justice system, the anti-corruption framework, media pluralism and freedom, and other institutional issues related to checks and balances. The country chapters, which rely on a qualitative assessment carried out by the European Commission, analyse new developments since the previous Report and the follow-up to the challenges and developments identified in the 2022 edition. The WJP developed the WJP Rule of Law Index as a quantitative tool that measures the rule of law in practice [51]. The Index's methodology and comprehensive definition of the rule of law are the products of intensive consultation and vetting with academics, practitioners, and community leaders from more than 100 countries and jurisdictions and 17 professional disciplines. The Index offers original, independent data organised into eight factors encompassing the rule of law: Constraints on Government Powers, Absence of Corruption, Open Government, Fundamental Rights, Order and Security, Regulatory Enforcement, Civil Justice, and Criminal Justice. Index factor scores reflect the perspectives and experiences of more than 149 000 everyday people and 3 400 legal experts worldwide, and a rigorous process of validation and analysis backs them (Source: WJP).

The WJP developed the conceptual framework summarised in the Index's 9 factors and 47 sub-factors in consultation with academics, practitioners, and community leaders from around the world [51]. The Index team developed a set of five questionnaires based on the Index's conceptual framework to be administered to experts and the public. Questionnaires were translated into several languages and adapted to reflect commonly used terms and expressions and then identified, on average, more than 300 potential local experts per country to respond to the expert surveys, or Qualified Respondents' Questionnaires (QRQs). The team engaged the services of leading local polling companies to implement the household surveys or General Population Polls (GPP). Polling companies conducted pilot tests of the GPP in consultation with the Index team and launched the final survey for full fieldwork. The Index team sent the QRQ questionnaires to local experts and engaged in continual interaction with them; collected and mapped the data onto the 44 sub-factors with global comparability; constructed the final scores using a five-step process. The data was subject to a series of tests to identify possible biases and errors. For example, the Index team cross-checked all sub-factors against more than 70 third-party sources, including quantitative data and qualitative assessments drawn from local and international organisations. The Econometrics and Applied Statistics Unit of the European Commission's Joint Research Centre, in collaboration with the Index team, to assess the statistical reliability of the results, conducted a sensitivity analysis. To illustrate whether the rule of law in a country significantly changed over the past year, a measure of change over time was produced based on the annual difference in the country-level factor scores, the standard errors of these scores (estimated from a set of 100 bootstrap samples), and the results of the corresponding t-tests. The data was organised into country reports, tables, and figures to

facilitate its presentation and interpretation. For tables organised by income group, the WJP follows the World Bank income classifications [51]. Besides, according to the official World Justice Project webpage, the Global Rule of Law Recession continues since, for the sixth year in a row, the rule of law has declined in most countries [51].

RESULTS

GLOBAL ANALYSIS

Table 1 gives an overview according to the income, presenting countries belonging to the high-income group. The change in rankings was calculated by comparing the positions of the 140 countries and jurisdictions measured in the 2022 Index with the rankings of the same 140 countries and jurisdictions in 2023, exclusive of the two new additions to the 2023 Index, Kuwait and Montenegro. Income groups used in the 2023 report are based on the World Bank's 2023 fiscal year income group classifications. For the 2023 fiscal year, low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of $1085 or less in 2021; lower-middle-income economies are those with a GNI per capita between $1086 and $4 255; upper-middle-income economies are those with a GNI per capita between $4 256 and $13 205; high-income economies are those with a GNI per capita of more than $13 205.

The highest overall Rule of Law score is reserved for the northern European countries (1/46 Denmark, 0,90; 2/46 Norway, 0,86; 3/46 Finland, 0,87; 4/46 Sweden, 0,85) and then also for developed central and western European Countries, i. e. Germany (0,83), Luxembourg (0,83), Netherlands (0,83), Estonia (0,82), Ireland (0,81) and Austria (0,80) (respectively 5/46, 6/46, 7/46, 9/46, 10/46 and 11/46) – all being at the level of 0,80 or higher. Croatia achieved a much lower rank, 40/46, in the high-income category, with a score of 0,61. Compared to last year, Croatia has risen by two places, thereby presenting positive change. The same score was recorded for Greece as well (rank 41/46, score 0,61), but Greece's annual overall score fell by -1,4%. Hungary was the only other European country that was lower than the score of 0,61 (rank 45/46, score 0,51). Additionally, some of the Central European and Eastern European countries usually record lower levels of some other indicators, i.e., The Economic Freedom Index is important for achieving economic success.

Table 2 gives an overview of the Rule of Law Justice Index ranks by the World Justice Project and by the Rule of Law group of indicators calculated as an average of the three indicators belonging to the group of the Index of Economic Freedom for the 27 European Union Countries.

The Index of Economic Freedom is comprised of 12 different freedoms, from property rights to financial freedom, in 184 countries. The Index of Economic Freedom confirms a positive relationship between economic freedom and progress. It consists of 12 indicators grouped into four pillars – Rule of Law (consisting of property rights, government integrity, judicial effectiveness), Government Size (consisting of government spending, tax burden, fiscal health), Regulatory Efficiency (business freedom, labour freedom, monetary freedom) and Open Markets (trade freedom, investment freedom, financial freedom).

For both indicators of the Rule of Law, there were used or calculated last available data. The methodology of the Index of Economic Freedom is that there are four categories made from 12 specific components of economic freedom, each of which is graded on a scale from 0 to 100. Scores on these 12 components of economic freedom are calculated from a number of sub-variables then equally weighted, and averaged to produce an overall economic freedom score for each economy. The listed sources explain the formulas and methodology used to compute the scores for each of the 12 components of economic freedom.

Table 1. Rule of Law by criterion of income, High-Income group (authors' work, based on [51]).

Income Rank	Country/ Justification	Overall Score	Annual Change in Overall Score, %	5-Year Change in Overall Score, %	Global Rank	Change in Global Rank
1/46	Denmark	0,90	–0,3	0,7	1	0
2/46	Norway	0,89	0,3	0,3	2	0
3/46	Finland	0,87	0,4	0,3	3	0
4/46	Sweden	0,85	–0,4	–1,1	4	0
5/46	Germany	0,83	0,0	–0,2	5	1
6/46	Luxembourg	0,83	0,8		6	2
7/46	Netherlands	0,83	–0,3	–2,5	7	2
8/46	New Zealand	0,83	–0,2	–0,4	8	1
9/46	Estonia	0,82	0,0	2,3	9	0
10/46	Ireland	0,81	0,3		10	0
11/46	Austria	0,80	–0,3	–2,0	11	0
12/46	Canada	0,80	0,5	–1,3	13	0
13/46	Australia	0,80	0,5	–1,3	11	0
14/46	Japan	0,79	0,0	–0,2	14	2
15/46	United Kingdom	0,78	–0,4	–3,1	15	0
16/46	Belgium	0,78	–1,0	1,2	16	2
17/46	Singapore	0,78	–0,1	–2,6	17	0
18/46	Lithuania	0,77	0,4		18	0
19/46	Korea rep.	0,74	0,5	2,0	19	0
20/46	Czech Republic	0,73	0,1	–1,3	20	0
21/46	France	0,73	–0,4		22	2
22/46	Latvia	0,73	0,7		22	2
23/46	Hong Kong SAR, China	0,73	–0,2	–6,0	23	1
24/46	Spain	0,72	–0,8	2,4	24	1
25/46	Uruguay	0,72	0,4	0,7	25	0
26/46	United States	0,70	–0,6	–4,0	26	0
27/46	Slovenia	0,69	1,6	2,3	27	4
28/46	Portugal	0,68	–0,9	–5,2	28	1
29/46	Malta	0,68	0,1		30	0
30/46	Cyprus	0,68	–0,9		31	3
31/46	Italy	0,67	0,0	2,0	32	0
32/46	Chile	0,66	–0,1	–0,7	33	0
33/46	Slovakia	0,66	0,3		34	1
34/46	Barbados	0,66	0,0	1,1	35	1
35/46	Poland	0,64	–0,6	–5,3	36	0
36/46	United Arab Emirates	0,64	0,2	–1,9	37	0
37/46	Antigua and Barbuda	0,63	0,6	0,7	38	2
38/46	St. Kitts and Nevis	0,63	–0,4	–4,1	39	0
39/46	Romania	0,63	–0,4	–4,1	40	2
40/46	Croatia	0,61	0,3	0,2	45	2
41/46	Greece	0,61	–1,4	–0,3	47	3
42/46	The Bahamas	0,59	–2,0	–1,4	50	2
43/46	Kuwait	0,58			52	-
44/46	Trinidad and Tobago	0,52	–0,8	–7,0	70	1
45/46	Hungary	0,51	–0,2	–6,0	73	2
46/46	Panama	0,51	-0,5	-1,2	74	0

Table 2. Rule of Law Justice Index in the European Union Countries (authors' work, based on [51, 52]).

Rank	Country/Justification	Rule of Law Justice Index 2023	Rule of Law Group by Economic Freedom Index, 2024	The Index of Economic Freedom 2024
1	Denmark	0,90	95,2	77,8
2	Finland	0,87	97,3	76,3
3	Sweden	0,85	94,9	77,5
4	Germany	0,83	91,4	72,1
5	Luxemburg	0,83	92,5	79,2
6	Netherlands	0,83	93,2	77,3
7	Estonia	0,82	89,1	77,8
8	Ireland	0,81	90,4	82,6
9	Austria	0,80	88,8	68,4
10	Belgium	0,78	87,3	65,6
11	Lithuania	0,77	77,1	72,9
12	Czech Republic	0,73	77,7	70,2
13	Latvia	0,73	75,1	71,5
14	France	0,73	83,7	62,5
15	Spain	0,72	74,9	63,3
16	Slovenia	0,69	80,2	65,9
17	Portugal	0,68	81,8	68,7
18	Malta	0,68	77,2	64,5
19	Cyprus	0,68	76,1	72,2
20	Italy	0,67	73,3	60,1
21	Slovak Republic	0,66	70,3	68,1
22	Poland	0,64	60,8	66,0
23	Romania	0,63	64,8	64,4
24	Croatia	0,61	67,4	67,2
25	Greece	0,61	67,3	55,1
26	Bulgaria	0,56	59,1	68,5
27	Hungary	0,51	59,0	61,2

It is evident that countries ranked at the bottom according to the Rule of Law Justice Index are also the ones where the Rule of Law Group calculated as an average of the indicators belonging to the group of Rule of Law according to the Economic Freedom Index (property rights, government integrity, judicial effectiveness) have a lower level of the Rule of Law Group compared to the Index of Economic Freedom overall score – visible from the results for Hungary, Bulgaria and Poland and with very small difference in-between overall Economic Freedom Index and the Rule of Law Group average for Greece, Croatia, Romania and Slovakia – being ranked as well by previously mentioned Rule of Law Justice Index among the last ones.

Institutional underdevelopment frequently appears as a cause and because of certain economic underdevelopment. Furthermore, [52] states that according to the level of trust in the police, trust in the legal system, trust in the political system and trust in others as a part of well-being indicators, countries of North Europe have higher rates of measured indicators (Norway, Finland, Sweden,…), while Central and Eastern European countries have lower level of trust in most indicators presented – named as well-being indicators [53]. The lower rank of Central and Eastern European Countries could also be explained by their transitional path in becoming independent democracies and the need to change in a political, societal, institutional, and economic way – and becoming more decentralised economies, achieving fiscal, functional, and

administrative decentralisation, in order to achieve better living standard. Although countries have made significant progress in their transition way, from one system to another, the weight of inheritance is still present to a certain extent, which can also be seen when comparing the competitiveness of individual NUTS 2 of certain national economies [54]. Suppose one looks at certain composite indexes, such as the Human Development Index, as a measure of the living standard of countries. In that case, the rank is very similar to those already mentioned. In the first five ranks for the Human Development Index are three countries from North Europe: Norway (2nd, 0,966), Denmark (5th, 0,952) and Sweden (5th, 0,952) [52].

CROATIAN POSITION

Furthermore, we analyse Croatia's profile according to the JWP Index (Tables 3-5) and demonstrate data according to the JWP official website. An analysis was made with the available information concerning other countries in the region that are also in the high-income group. The score ranges from 0 to 1, where 1 signifies the highest possible score, and 0 signifies the lowest possible score.

According to the given data, the regional rank and income rank are marked as low. Furthermore, the overall score of 0,61 is considered a medium value, considering that 1 represents the highest possible value. Croatia has increased by two places compared to 2022 in rank range, Table 3.

Table 3. The overall rule of law score for Croatia for 2023 [51].

Indicator	Croatian score
Overall score	0,61 ↑
Global rank	45 / 142 ↑
Regional rank	28 / 31 ↑
Income rank	40 / 46
Rank change	+2 ↑
Score change	0,00 ↑

Table 4 presents the score for various aspects, which is much lower for Croatia for the following fields: Criminal Justice (0,51), Regulatory Enforcement (0,56), Civil Justice (0,56), Absence of Corruption (0,57) and Constraints on Government Powers (0,58). The best field of eight listed for Croatia was Order and Security (0,84). Therefore, these five fields are the main obstacles to better governance and improvement of the rule of law of the Croatian economy and, therefore, consequentially, institutions as well.

Table 4. Croatia's factor score for the rule of law in 2023 (author's work based on [51]).

	Score	Global average	Regional average	Global rank	Regional rank	Income rank
Constraints on government powers	0,58	0,54	0,74	53/142	28/31	39/46
Absence of coruption	0,57	0,51	0,73	50/142	26/31	40/46
Open government	0,61	0,52	0,72	37/142	26/31	34/46
Fundamental rights	0,68	0,56	0,77	37/142	25/31	34/36
Order and security	0,84	0,72	0,86	31/142	21/31	29/46
Regulatory enforcment	0,56	0,54	0,72	50/146	28/31	41/46
Civil justice	0,56	0,54	0,69	58/146	28/31	42/46
Criminal justice	0,51	0,47	0,66	54/146	28/31	41/46

Table 5 shows Croatia's global score in relation to all eight factors according to WJP, with 0 representing the lowest possible score and 1 representing the highest possible score.

Table 5. Croatia Rule of Law Score Over Time, 2015-2023 (authors' work based on [51]).

Year	Rule of Law Score
2015	0,60
2016	0,61
2017-2018	0,61
2019	0,61
2020	0,61
2021	0,61
2022	0,61
2023	0,61

According to the data in Table 5, it is evident that the index itself has changed very little; it has remained at the same value for years, i.e. for the 2016-2023 timeframe.

LIMITATIONS

The Index methodology has both strengths and limitations. Among its strengths is the inclusion of both expert and household surveys to ensure that the findings reflect the conditions experienced by the population. Another strength is that it approaches the measurement of the rule of law from various angles by triangulating information across data sources and types of questions. This approach not only enables accounting for different perspectives on the rule of law, but it also helps to reduce possible bias that might be introduced by any other particular data collection method. Finally, statistical testing is used to determine the significance of the changes in the factor scores over the last year.

With the strengths above, there are a number of limitations. First, the data sheds light on rule of law dimensions that appear comparatively strong or weak but are not specific enough to establish causation. Thus, it will be necessary to use the Index in combination with other analytical tools to provide a full picture of causes and possible solutions. Second, in previous editions of the Index, the methodology has only been applied in three major urban areas in each of the indexed countries for the General Population Poll. However, the World Justice Project's goal was to update its methodology to include nationally representative polls. Towards this end, nationally representative polls have been conducted in 83 countries and jurisdictions covered in the 2023 WJP Rule of Law Index. Nationally representative polls will be conducted in the remaining countries in future editions of the Index. Third, given the rapid changes to the rule of law occurring in some countries, scores for some countries may be sensitive to the specific points in time when the data was collected. To address this, the WJP is piloting test methods of moving averages to account for short-term fluctuations. Fourth, the QRQ data may be subject to problems in measurement error due to the limited number of experts in some countries, resulting in less precise estimates. To address this, the WJP works constantly to expand its network of in-country academic and practitioner experts who contribute their time and expertise to this endeavour. Finally, due to the limited number of experts in some countries (which implies higher standard errors) and the fact that the GPP is carried out in each country every few years (which implies that for some countries, some variables do not change from one year to another), the test described above may fail to detect small changes in a country's situation over time (source: WJP).

The rule of law is increasingly viewed as a factor of economic growth that is no less important than capital and labour, technological innovation, geographical location, economic openness or cultural characteristics [55].

Predominately, the conclusions about the constructiveness of the rule of law are based on cross-regression, which may have significant limitations because it does not consider the particularities of some countries. As a result, it is better to use panel data estimation methods with fixed, variable effects [56].

Moreover, countries with historically established rules of law are usually compared to countries that lacked such an institutional feature in the past. The correlation between successes in achieving the rule of law and economic growth can be reciprocal when strengthening legal frameworks increases with income. Moreover, countries with historically established rules of law are usually compared to countries that lacked such an institutional feature in the past. The correlation between success in achieving the rule of law and economic growth can be mutual when strengthening legal approaches occurs together with an increase in income.

CONCLUSION

The Rule of Law is recognised as an element that indicates the justice system and its fairness, the level of respect for human rights, the effectiveness of democracy, and sustainable development in a certain country. According to the chosen theoretical and secondary data, this article gives an overview of the interconnection between the rule of law, governance, and economic growth. Knowing that strong governance minimises macroeconomic instability, it is easy to conclude that it builds a positive path to achieving economic growth and development.

According to the data presented in the article, the rule of law is weakening. It is very worrying that about 6 billion people live in countries where the Index is decreasing, as measured by the research defined by the Rule of Law Justice Index.

The Rule of Law Justice Project offers an extended insight into the Rule of Law to provide insight to many stakeholders on possible weaknesses, strengths, developments, and setbacks across 142 countries and jurisdictions covering eight areas: Constraints on Government Powers, Absence of Corruption, Open Government, Fundamental Rights, Order and Security, Regulatory Enforcement, Civil Justice, and Criminal Justice. Given the available data, it is evident that in 2023, in general, the rule of law is in decline in most countries. Some countries have managed to weaken authoritarian trends, while some countries have sustained progress in relation to the protection of human rights, the rule of law, and anti-corruption measures. The mentioned indications are that progress is possible in all measured segments of the Rule of Law. According to the income groups, the classification was made according to GNI per capita in 2021, as follows: i) low-income economies, $1085 or less; ii) lower-middle-income economies, in-between $1086 and $4 255; iii) upper-middle-income economies, in-between $4 256 and $13 205; iv) high-income economies, more than $13 205. All countries of the European Union belong to the high-income economies but with a pronounced gap in the overall Rule of Law Justice Index. Further, countries in North Europe, such as Denmark, Norway, Finland, and Sweden, have the highest rank and score on the Rule of Law Justice Index. Besides the first few rankings of northern European countries, other EU countries are also recording high scores on the Rule of Law Justice Index, for instance, by the following order: Germany, Luxembourg, Netherlands, Estonia, Ireland, and Austria. All mentioned countries are above the 0,80 Rule of Law Justice Index score. Other EU countries below that score, were above 0,70 were the following countries: Belgium (0,78), Lithuania (0,77), Czech Republic (0,73), Latvia (0,73), France (0,73) and Spain (0,72). All other EU countries are below the 0,70 score – which is almost half of the EU countries, i.e., 12 EU countries. Most of them are former transitional Central European Countries (Slovenia, Slovakia, Poland, and Hungary), Eastern or

South-eastern European Countries (Romania, Croatia, Bulgaria) or Mediterranean countries (Malta, Cyprus, Italy, Greece).

According to some other indexes that measure the rule of law, i.e., the Rule of Law Group of indicators calculated as a part of the Economic Freedom Index, very similar results are confirmed. The difference in the overall score of the Index of Economic Freedom and the Rule of Law Group of Economic Freedom Index is very small for the countries that are ranked at the bottom of the rank compared to the ones at the best positions according to the Rule of Law Justice Index.

Based on the Rule of Law Justice Index for 2023, the regional rank and income rank are marked for Croatia as low, according to the given data. Furthermore, the overall score of 0,61 out of 1 is considered a medium value. Croatia has increased by two places compared to 2022 in rank range. The same score was recorded for Greece as well (rank 41/46, score 0,61), but Greece's annual overall score fell by –1,4%. Bulgaria and Hungary were the only other European countries that had lower scores than 0,60 (0,56 and 0,51, respectively). The worth of emphasising is as well that besides the lower level of the Rule of Law Justice Index, in other related areas of measurement and indices (Economic Freedom Index, level of trust), countries of Eastern Europe and some of Central Europe still record lower levels. Therefore, improvements at the institutional level, governance and the rule of law should be of great importance for all countries, especially for the countries that are least developed.

Conclusively, we recommend that future studies extend the literature by analysing the rule of law index in comparison with previous years in order to obtain a deeper analysis or the analysis for the previous six years since the beginning of the rule of law justice index measurement.

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MORE DIGITALIZED HEALTH SERVICES: A BLUEPRINT FOR A CENTRALIZED SOFTWARE APPLICATION IN SMART CITY CONTEXT

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ABSTRACT

This article introduces a new computerized solution designed to address the connectivity needs of a medical assistance system within the smart city context. To simulate the main developed functionalities, existing workflows from the medical system of Romania were selected as a case study. The developed information application is based on Java and Android ecosystems. It includes a desktop interface for system management addressed to medical specialists, and a mobile one accessible to patients. The platform's capabilities include scheduling and search functionalities for hospitalization and consultations, categorized by medical specialty and institutions, all managed centrally at the city level. The solution incorporates tools for both in-person and remote interactions between healthcare providers and patients. This encompasses discussion functionalities for remote consultations and the ability to monitor medical parameters collected from smart devices or voluntarily transmitted by the patients. Patient data is securely stored in a digital record containing anamnesis and medical observation details, including imaging features. These are also anonymized and labelled with the diagnosis provided by medical specialists, becoming a resource for diagnosing patients with the same pathologies, complying with medical ethics. These are analysed using Machine Learning and Deep Learning algorithms optimized to generate accurate results. The models are pre-trained with medical nature datasets from online repositories. Furthermore, the system's adaptability and resilience can become an asset in addressing health crises, such as the ongoing COVID-19 pandemic. This reinforces the city's ability to respond effectively to unforeseen challenges.

KEY WORDS

e-healthcare, smart resilient city, medical application, data analysis

CLASSIFICATION

JEL: I18, L86, O33

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INTRODUCTION

In recent years, there has been a significant increase in public concern regarding urban development, public health, and technological innovation. The concepts of smart cities, digitization, Artificial Intelligence (AI), e-governance, and e-healthcare have emerged as elements that are reshaping the landscape of modern life. As cities evolve into dynamic hubs of connectivity and innovation, the integration of sensors, wireless networks, and automated data processing is emerging as a transformative force that can improve various aspects of citizens' lives. In the context of recent global events, the most significant being the COVID-19 health crisis, the critical role of modern technologies in strengthening the resilience of cities was emphasized, especially in managing the situation of the healthcare system [1] which can be seen as a complex system [2]. The adoption of smart technologies has become vital for re-evaluating and optimizing urban management strategies, providing not only convenience but also a necessary approach. The resilience and responsiveness of cities in crisis situations are directly influenced by their ability to capitalize on data, connectivity, and AI [3] to quickly respond to various challenges.

Smart cities must be regarded from a holistic perspective, where public services and physical infrastructure are coordinated and managed integratively to create a harmonious urban environment. The fundamental pillars on which the smart city is based are citizens, infrastructure, and urban planning [4], involving an integrative framework incorporating cutting-edge digital tools and data interpretation. Essential public services, such as education and health, are becoming more interactive and connected, aided by current educational approaches [5] and the use of sensors and data analysis for health assessment [6]. Related to infrastructure-the energy, and transport receive new approaches that lead to reducing consumption, optimizing the use of resources, increasing efficiency, transitioning to the use of alternative sources [7], and large-scale implementation of autonomous vehicles, and intelligent roads, traffic lights and parking systems [8]. Urban planning and management can be improved by analyzing data to anticipate city needs and making better-informed decisions by simplifying information from the city's complex network of interconnections [9].

Figure 1. Main pillars on which smart cities are based [10].

It has been demonstrated that health services must be brought to the forefront, particularly in light of the COVID-19 pandemic, which underscored the critical necessity for more sophisticated and interconnected health information systems [11]. Centralization of medical services within smart cities should become a priority for the authorities, changing the way medical services are provided and accessed in urban environments. Well-developed technical capabilities can: promote preventive measures, enable remotely collaborative work between teams of physicians, facilitate remote patient monitoring by medical professionals and telemedicine services, forecast the spread of diseases, monitor nutrition lifestyle, monitor vital and environmental parameters, create independence for people with disabilities by dedicated equipment, realize clinical trials helping in diseases prevention and spreading, or improve preparedness in case of calamities [12-14].

The concerns of nowadays medicine go beyond the simple diagnosis of patients and the provision of treatments. The focus has shifted more toward the prevention and integration of computer technology that facilitates the storage of medical data and monitoring of patient health status. These data can then be used for early detection and various preventative therapies. Thus, emphasis is placed on the proactive side of medicine, which promotes the early identification of risk factors and intervention in the early stages of various pathologies. Medical monitoring devices can play an essential role in the assessment of a patient's health status. Many health facilities use devices with limited connectivity capacity, that allow only local operations. However, the data provided by these types of non-smart devices can be used by integrating them into a processing and storage infrastructure to make them accessible in a centralized manner [15]. There is also another category of semi-medical wearable tools, such as smartwatches, fitness bracelets, or various sensors, that can monitor and warn of changes in health parameters that integrate connectivity capacities. Some devices can be used to monitor physiological signals like Electrocardiography. Others provide biometric measurements like Blood Pressure, Heart Rate, Pulse Oxygen Saturation, Temperature Sensor, or the evaluation of body movements like Pedometer, Gyroscope, Accelerometer [16]. The existence of several protocols and computer systems in which semi-medical devices are integrated makes data exposure heterogeneous. Careful management of diverse data standards and formats is essential for providing accurate transfer of medical data [17]. Since these devices are used unconventionally, the obtained data are for informational purposes only.

The use of a more digitalized infrastructure in the field of health can be a real help. This is because it contributes to reducing bureaucratization, secures and stores relevant information on the health status of patients; removes redundant data from the system, avoids errors, and increases the efficiency of medical staff by improving the process of providing medical services. This allows the medical staff to focus more on the medical act and less on the preparation of documents. The implementation of new technological tools can allow better integration of patient data, leading to a reduction in the costs of services, both for diagnosis and treatment and for better monitoring and patient care [18]. Solutions must be found to meet the objectives of improving data flows between medical institutions, improving the quality of medical services, and improving the health status of the population.

Online appointment platforms for medical units are essential tools for enhancing the quality of healthcare services. These tools establish a direct connection between patients and medical service providers, enabling rapid access to programs for consultations, analyses, and investigations. This contributes to building a more accessible medical experience [19].

For the management of patients' medical data, three types of information systems have been identified in the specialized literature: Electronic Medical Records (EMR), Electronic Health Records (EHR), and Personal Health Records (PHR) [20]. EMRs are used to optimize internal processes, at the level of a healthcare unit, providing restricted access only at its level. EHRs

allow for coordinated management of data between various medical service providers. Implementing this type of system at the macro level faces challenges in managing high volumes of medical data, as well as from a technical point of view. PHRs offer patients control over their health information, as well as the ability to complete their personal medical data through platforms that are accessible to patients. The limitations of this model are represented by patient involvement and data security management challenges. However, a comprehensive solution that encompasses functionalities to meet both patient and sanitary units' requirements while promoting a centralized approach to improve interoperability between various systems is desirable.

Not only the storage of medical data is important, but also their analysis. Machine Learning (ML) and Deep Learning (DL) are powerful information technology tools with significant potential for use in the medical field. Their application can create a substantial impact. The use of ML in analyzing medical records, predicting diseases, and interpreting results enables medical professionals to make more informed decisions regarding the diagnosis and treatment of diseases [21]. For patient diagnosis, DL integration for medical image analysis enables detailed exploration of visual information, identifying complex patterns that may be difficult to detect with the unaided eye, by analyzing large data sets. [22]. This process may involve using Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Generative Adversarial Networks (GANs), or hybrid models to automatically extract relevant features from images, such as textures, edges, and anatomical structures, which are then used to substantiate the diagnosis. This approach provides greater sensitivity and specificity in the detection and classification of multiple medical pathologies, contributing to the development of more accurate and reliable diagnostic methods [23]. DL algorithms can be integrated for application on standardized image formats, such as those based on the Digital Imaging and Communications in Medicine (DICOM) protocol. This type of medical imaging file contains, in addition to a collection of images, multiple metadata that can be used to create powerful models to diagnose patients with or without certain diseases [24]. The images are automatically compared with training data inputs. Optimizing the learning models leads to high accuracy scores in fitting data into the correct classes, relative to the trained models [25]. Users who interact with the system receive predictions regarding potential diagnoses by performing minimal informatic operations [26].

Concerns regarding IT implementations to revolutionize the medical field are currently targeted by the global tech giant Google. Recently, Google introduced a model based on generative AI called MedLM [27]. This is based on Large Language Models (LLMs), called Med-PaLM, which is currently in its second iteration, and will soon integrate the new Gemini model. In the current form, the model is in the testing phase, being integrated with Natural Language Processing (NLP) tools in building systems to assist the conversation between the patient and the doctor, converting the data directly into the medical record, eliminating the need for manual transcription. Such methods of conversation-based interaction can help to extract relevant details regarding the consultation and self-completion of medical forms, generating personalized documents [28].

The aim of this paper is to introduce a health informatics solution that is useful in a smart city setting. To emphasize the main functionalities, some medical procedures and protocols at the Municipality of Bucharest sanitary system level were analyzed, and the elements that could be computerized were transposed into the informatic test application. The solution approaches functionality exploration in a manner that respects data privacy. Thus, the technical implementation focuses on testing and evaluating capabilities, without involving the capture or storage of personal data of real patients, performing simulations on fictitious data to demonstrate the potential in the medical context. The structuring of medical information respects the content addressed by other national medical programs, focusing on the flows

identified in the modeling stage. This includes two IT modules – a desktop version for medical specialists and a mobile version for patients. The application offers the possibility of city-centralized scheduling of patients. In addition, it emphasizes the importance of semi-medical devices data extraction and analysis. The medical records data are analyzed through ML and DL algorithms to provide potential diagnostic suggestions and warnings.

The article is organized into four main sections. The second section provides an overview of the Romanian medical system, aiming to clarify the interdependencies and identify the main involved actors. In the third section, the methodological approach is introduced, which includes system modeling and information flow. The fourth section presents the main results and discussions. In the final section, the conclusions are outlined.

OVERVIEW OF THE ROMANIAN MEDICAL SYSTEM

History has shown that modern medicine in Romania developed from the middle of the 19th century, when attention to this field intensified. The emphasis was initially focused on diagnosis and treatment, and many Romanian specialists and doctors achieved remarkable results in their research and were recognized worldwide. Advancements in technology, reforms, and innovations from the public and private sectors have contributed to continuous improvements and alignment with international standards.

At present, medical services are demanded by a large number of patients; therefore, healthcare involves high costs from the state. Currently, in Romania, access to public medical services is achieved through a contributory system. The health system is financed from funds collected from various sources [29]:

- For the national health system, it is made from direct and indirect taxes;
- For the social health insurance system, it is made from mandatory contributions;
- For the private system, it is made from voluntary insurance policies;
- For the free market system, it is made from direct payments by the beneficiaries;
- Other financing sources (European funds, private sources, etc.)

Funds are administered by various entities, including government departments, ministries, insurance companies, public insurance funds, etc.

The health care sector is an important branch of a smart city, and for its renewal and development as efficiently as possible, it is necessary to integrate actual informatics technologies and smart solutions [18]. In Romania, this stage was triggered by the implementation at the national level of a unique integrated system, called “SIUI”, which allows interconnection with various systems, e.g. the National Health Card, the Electronic Prescription, but also with other applications and systems of diverse medical institutions [30]. The information system allows the healthcare industry to manage and deliver medical assistance. The rapid advancement of technologies and high-speed computer connections can facilitate cost reduction and streamlining of the time allocated to medical services. Moreover, there is a need to store and rapidly analyze large volumes of data generated within the system. Thus, scaling the system is a continuous requirement.

Although the premises for an intelligent medical informatics system exist in Romania, it still requires the integration of the most recent information technologies to make better use of the infrastructure and resources to meet the needs of citizens. Expanding the system can facilitate capitalizing on data from various medical disciplines. The large scale introduction of electronic files in which each patient has stored their medical data would replace the need for archives in a physical format. These archives are difficult to manage and can be easily damaged. With an interconnected network at the city or national level, teams of specialists would be able to access

the data easily and quickly. Fragmentation of medical data leads to difficulties in quick access in critical situations.

Romania's medical system is subject to national legislation and is supported by both state and private hospitals. These are equipped and operate according to the specific needs of each pathology, including general medicine, emergency, specialist, or chronic disease hospitals, more detailed in Figure 2. A hospital can include wards, diagnostic and treatment services, departments, and laboratories, and can provide specialized outpatient, hospitalization, and home care services. State hospitals are organized and operate according to territorial boundaries, ranging from regional to county, municipal, city, and communal facilities [31].

Figure 2 shows part of the existing links within the medical system in Romania and the main actors involved – beneficiaries and providers of medical services.

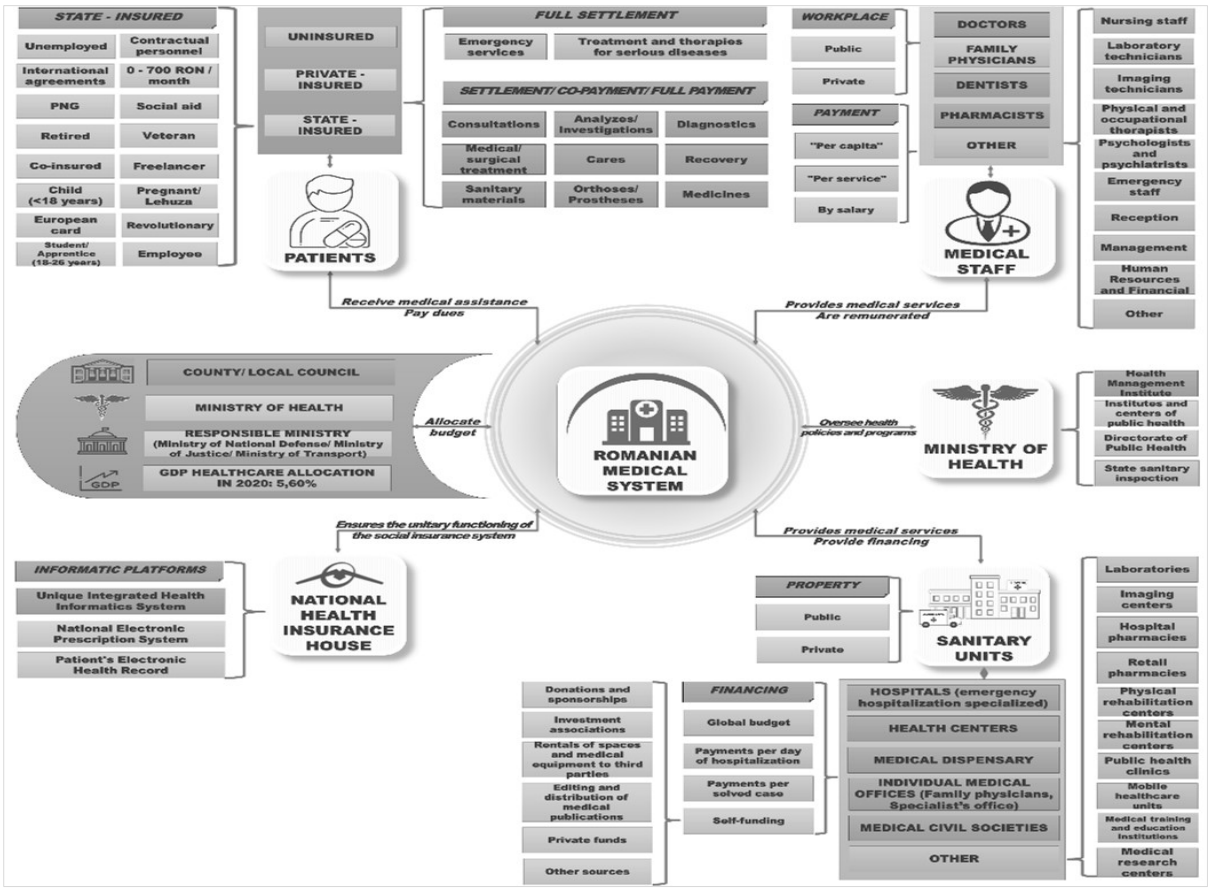

Figure 2. Overview of the Romanian medical system interdependencies.

In particular, this study focuses on understanding in depth the medical situation at the level of the Municipality of Bucharest. This is a complex and dynamic city, where factors such as population density, medical infrastructure, access to health services and individual behaviors directly influence the health of the community. From a statistical point of view [32], at the end of 2022, Bucharest had a total of 20 386 beds in public hospitals and 2 340 beds in the private sector. This places it at the top of the European ranking in terms of beds per 100 000 inhabitants, with 1 319 beds in both sectors per 100 000 resident population. From the perspective of the categories of medical assistance units, Table 1 shows the distribution according to the type of ownership – public or private. Out of the total of 52 state hospitals within the radius of the city, 24 hospital units are subordinate to the Ministry of Health; 19 sanitary units are managed by the Bucharest City Hall, 2 by the Ministry of National Defense, 2 by the Ministry of Justice, 2 by the Ministry of Transport, 1 by the Ministry of Internal Affairs, 1 by the Directorate of Public Health, and 1 by the Romanian Academy.

Table 1. Categories of sanitary units depending on the property type.

Categories of health facilities	Number of public units	Number of private units
Hospitals	50	28
Hospital units with day hospitalization only	2	28
Specialized outpatient clinics	6	24
Outpatient clinics integrated into the hospital	44	2
Polyclinics	-	9
Medical dispensary	6	-
Health centers	2	-
Mental health centers	7	-
Social and medical units	1	-
Diagnostic and treatment centers	4	-
Specialized medical centers	-	572
Dialysis centers	4	4
Work points of dialysis centers	-	5
School medical offices	477	-
Student medical offices	10	-
Family medical offices	2	1 388
Civil medical society	-	2
Dental offices	6	3 409
School dental offices	149	-
Student dental offices	13	-
Civil medical dental society	-	14
Specialized medical offices	-	2 199
Specialized medical civil society	-	24
Pharmacies, Pharmaceutical points, Pharmaceutical warehouses	62	891
Medical laboratories	395	654
Dental technology laboratories	6	252
Transfusion centers	3	-
Other types of medical offices	23	358

To understand the complexity of the medical system of the city of Bucharest, an important aspect is the medical personnel involved in the provision of services, both in the public and private sectors. Thus, the principal categories of professionals involved in medical assistance are summarized in Figure 3.

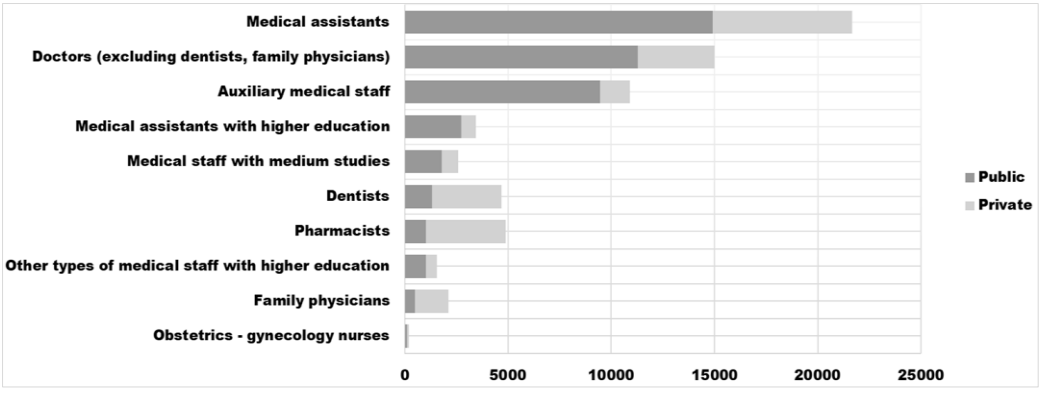

Figure 3. The number of medical personnel by category and work environment.

METHODOLOGICAL APPROACH

SOFTWARE APPLICATION MODELING

The methodological approach included the stages traditionally associated with developing an software application. The process starts with the analysis of the needs that the IT solution must fulfill, and structuring through specific diagrams. The application was modeled through the design of the architecture, database, modules, and interfaces with the user. Finally, the functionalities were effectively implemented and the proposed software application was tested.

The requirements for the IT solution were modeled using diagrams that highlight the existing links between the main identified actors that trigger various sequences of actions, called use cases. The Unified Modeling Language (UML) was used to perform modeling, allowing for the specification of the system's requirements and implementation approach. This enabled the creation of an overview prior to the actual implementation. UML can also be used to generate object-oriented scripts [33]. In the analysis stage, UML behavior diagrams, specifically use case diagrams, were utilized to identify, clarify, and organize the technical requirements, the actors involved, their roles within and external to the system, and the relationships between them. Building a use case diagram consists of using the elements from Figure 4.

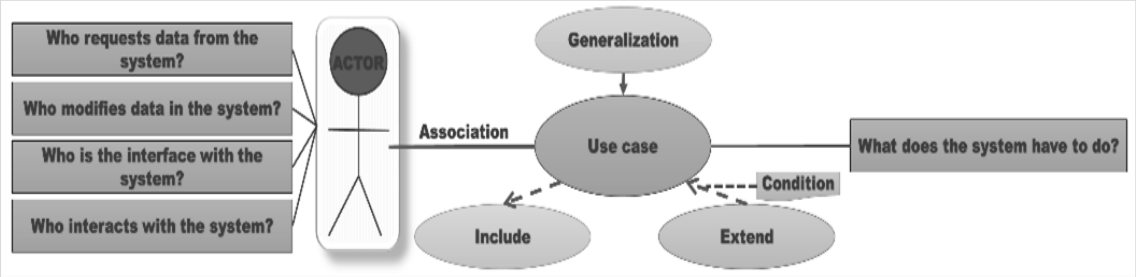

Figure 4. The main elements for building the use case diagram.

To successfully implement the software application, six primary actors were identified. Thus, *Patient* can use the smartphone device to create a user account (pre-verified by a healthcare specialist) to authenticate. They can schedule an appointment for a consultation or investigation with one of the medical service providers, and they can also check the medical history stored in the electronic medical record. They also benefit from medical services, according to their status in the medical system. Patients who have devices that measure fitness parameters send reports to the doctor who has them under observation. They can send feedback and read reviews given by other patients relating to the medical services offered by the medical units. The *Receptionist* manages appointments and checks insurance status. The *Medical Staff* offers consultations, analyses, investigations, or other medical procedures. Formulates diagnoses and prescriptions. Offers medical services according to working hours. The *Pharmacist* dispenses medicines according to the medical prescription with compensated payment or with full payment. The *HR/Financial* manages the schedule of doctors and the smooth running of the economic-financial situation. The *Administrator* of each medical unit and the one at the centralized level, manage the smooth running of the sanitary unit flows, respectively the real-time overview verification of the entire software application. Figure 5 shows the main requirements and the actors involved.

Sanitary units, focusing on public institutions, must have computerized records regarding medical services designed in a well-organized and efficient manner. This facilitates the management of medical documents. This approach allows the circulation of medical documents between medical units and patients in real-time. The flow of documents between the issuer of the medical document and the beneficiary – the patient – must be managed in a computerized, standardized, and unified way for all units to maximize work capacities.

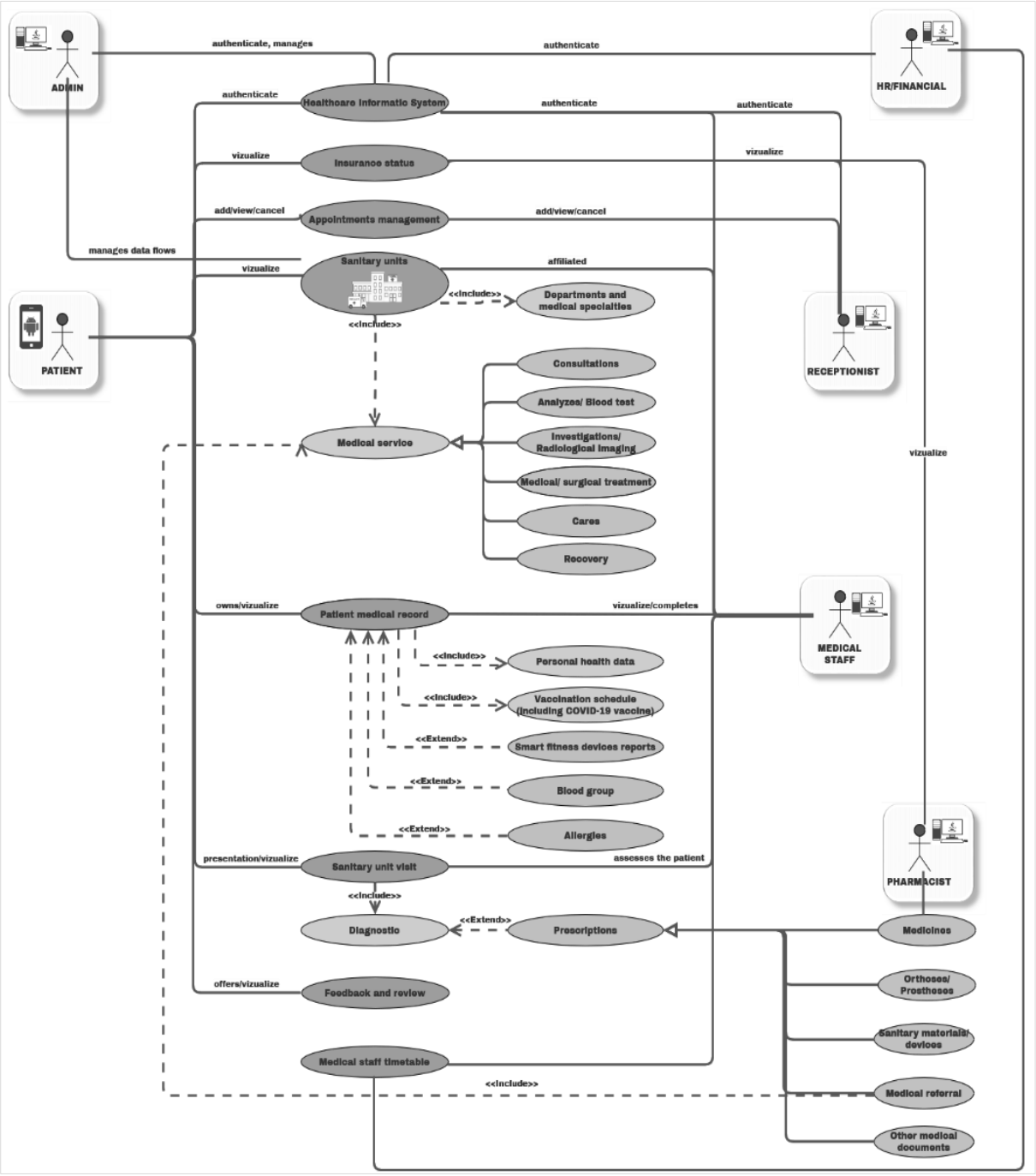

Figure 5. The software application - General UML diagram.

A well-structured scheduling management system can eliminate overlaps in the ambulatory consultation program, provide real-time updates on the number of beds available for hospitalization, list the services offered within each clinical specialty, monitor fund settlements, and display the number of investigations that can be supported with allocated funds.

COMPUTERIZED FLOW

The proposed software application offers an integrated approach that considers not only the perspectives of medical units and doctors but also those of patients. They remain interconnected to the medical information application through a centralized desktop and mobile platform. In the backend, the Java API is the gateway to the main data flows. The developed API is based on REST, and has predictable and intuitive URLs organized around the resources.

Built-in HTTP functions are used to issue requests (HTTP methods). All API endpoints return content in JSON format with the HTTP header "Content-Type: application/json" encoded using the UTF-8 character set. In the case of the REST architecture, the client invokes the web service by sending a GET/POST/ PUT/DELETE request. A response is returned after the request is processed. This architecture enables the exchange of information between the two frontends, which serve as interfaces with users. Data storage is achieved using an Oracle database with multimedia capabilities, which provides persistent, secure storage and allows regular data back-ups and recovery. The ML and DL algorithms integrated in the backend provide personalized recommendations based on the integrated data. These recommendations are continuously enriched with data from newly consulted patients. This provides a proactive approach for diagnosing patients. The mobile application uses a local SQLite database in the backend to manage the data retrieved from the fitness SDK. These data are refined locally and sent to the application in the form of summary reports. Communication between medical specialists, as well as between patients and doctors, is conducted through a Firebase chat server. Firebase Realtime Database services are used to store and retrieve messages. Firebase Cloud Messaging is used to notify users when new messages are received. Figure 6 shows the workflow within the information solution:

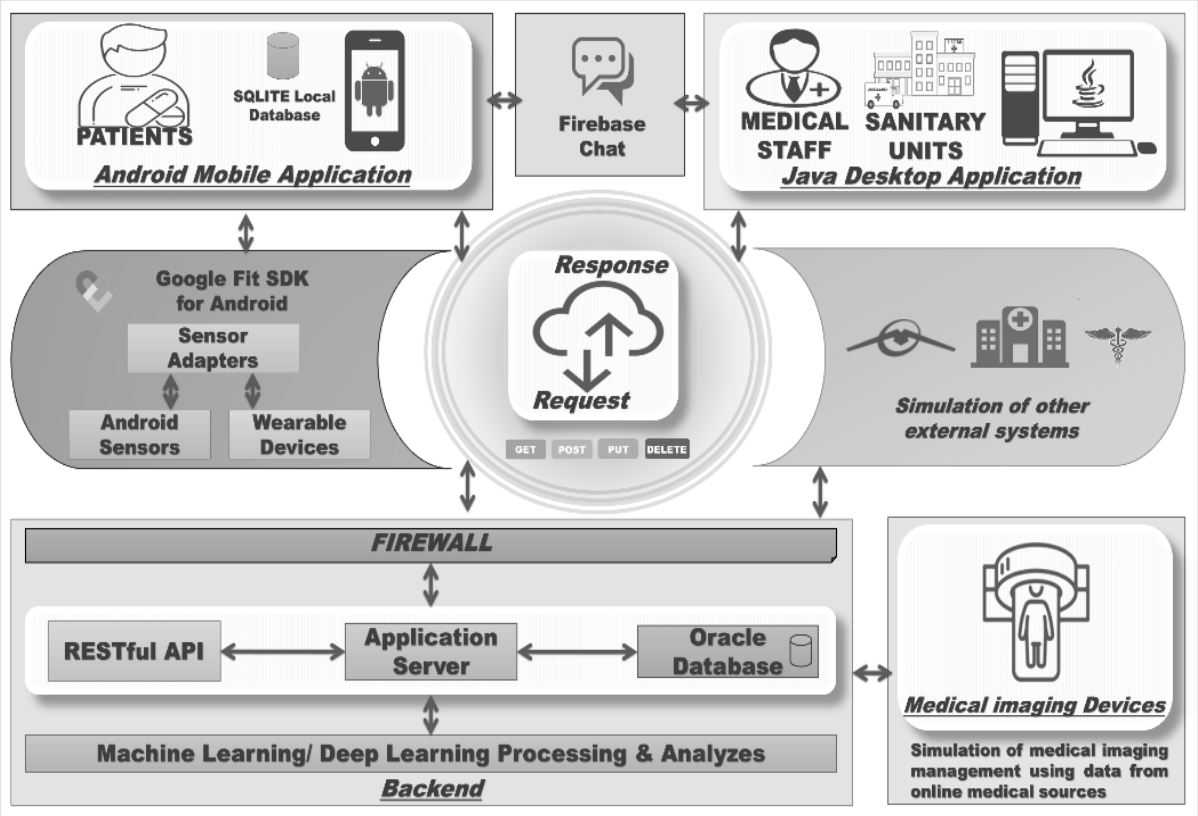

Figure 6. Application flow diagram.

RESULTS AND DISCUSSION

THE TECHNICAL DEVELOPMENT OF THE PROPOSED APPLICATION

The mobile version was implemented using the Android Studio Integrated Development Environment (IDE), API version 33, which is optimized for smartphones and tablets. By studying the situation at the updated level of active devices, it was found that Android 13 is a suitable version for a very varied range of devices. It has a coverage of approximately 30,37% of active devices in Romania during the period January-October 2023 [34]. Android Studio is

a flexible development environment that allows the use of emulators with various device configurations to test the behavior of the application in various scenarios.

The mobile version of the application was designed using "RelativeLayout" activities containing "ScrollView" containers to ensure visibility on various smartphone display sizes. For the same purpose, scaled and optimized backgrounds were used. Buttons have been designed to simplify the interaction between activities; also, fields limit inputs to prevent erroneous data from being entered. The existence of a network connection is verified when requests, queries, and synchronization that require an active connection are made. The local SQLite database manages the data, processes it, and then transmits simplified reports to the centralized solution to avoid overwhelming it with excessive data.

The resulting test application is fully functional and meets the initial proposed requirements. In the first activity, the patient logs in with existing credentials or creates an account as shown in Figure 7a. Creating a new user involves validating the account in the medical interface to confirm the user's identity. The patient is welcomed by the start interface, which provides a list of medical units that can be filtered by specialty or institution name, as shown in Figure 7b. Filtering enables users to quickly locate the desired medical unit, with the recommended results appearing as they type, as shown in Figure 7c. Patients can view a filtered list of hospitals that adhere to the specified restriction – hospital name/specialty.

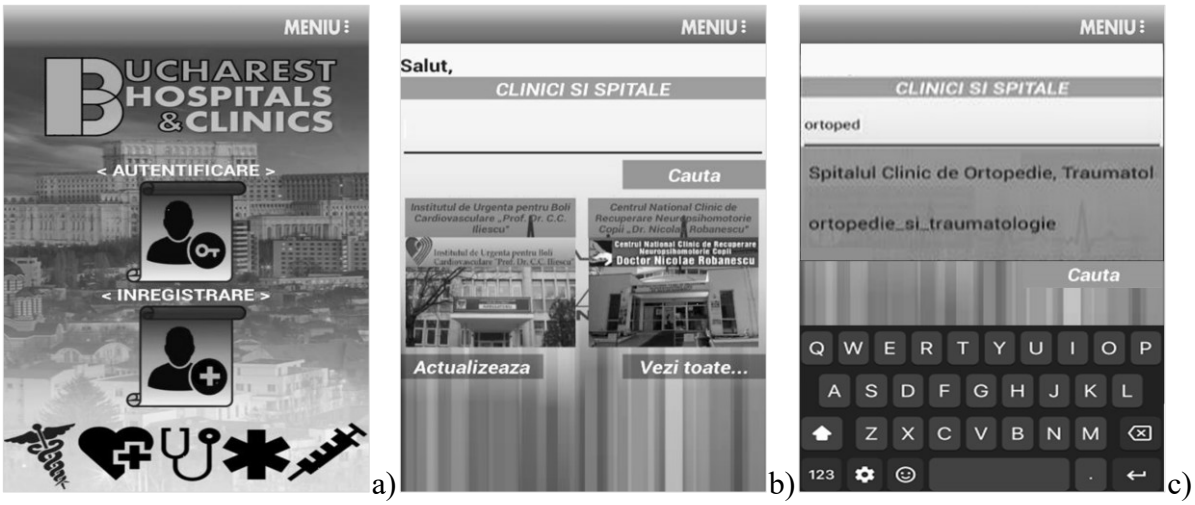

Figure 7. Mobile application interfaces: a) login activity, b) list of Bucharest medical units, c) cearch for a medical unit/ specialty.

By selecting the agreed hospital, its full name, direct phone call buttons, sending email, the map with the location of the hospital, the website, as well as other detailed contact data are displayed. On the same interface, the available specialties are presented and can be navigated with a scroll; a general score on the quality of medical assistance offered by each sanitary unit is presented. Selecting one medical specialty leads to a new activity that presents medical services, medical specialists, and the intervals in which they offer consultations. From here, the interval and service that the patient wants to benefit from can be selected. Appointments can be made either for in-person or remote consultations. Making an appointment is completed by exporting to the phone's Calendar the day and time slot in which the patient will receive the medical consultation. The mobile application exposes patient medical history records, general and seasonal vaccination calendars, medical records from devices connected via the native SDK or Google Fit, blood groups, allergies, and stored medical documents, such as medical imaging and prescriptions.

The authorization flow for accessing Google Fit data is realized by requesting multiple Android permissions. The connection is made through OAuth with Google credentials. Being a test application, and used for medical care purposes, it falls within the use cases provided by Google Fit. The obtained data are in the form of DataSet objects containing data points with timestamps and the fitness values, such as Steps, Heart Rate BPM, Blood Pressure Systolic/Diastolic, Oxygen Saturation, etc. Aggregate level data are requested, for example minimum, maximum, or average values over a time interval for Heart Rate. Queries are performed periodically and are stored in the local Android SQLite database. Aggregated reports are periodically sent to the centralized application.

The data transmitted by the devices undergo ML analysis, offering alerts to potential health problems by comparing them with trained data obtained from patients with certain pathologies. For example, during the COVID-19 pandemic, the integration of Heart Rate data in the determination of possible infection with coronavirus was explored [17]. However, these analyses also extend to the early detection of other pathologies, within the limits of the accuracy of the devices with the help of which the measurements are made and the conditions in which measurements are taken.

Similar to the Android version, intuitive interfaces were implemented for the Desktop application intended for medical staff. These interfaces were implemented with Java FX elements, using various types of containers and controls. The first graphical interface is the Authentication Form, shown in Figure 8a, which ensures a secure connection to the solution. The main page follows after login with a customized menu specific for the navigation of each type of user - Receptionist, Medical Staff, Pharmacist, HR/Financial, and Administrator; the receptionist interface is shown in Figure 8b.

a) b)

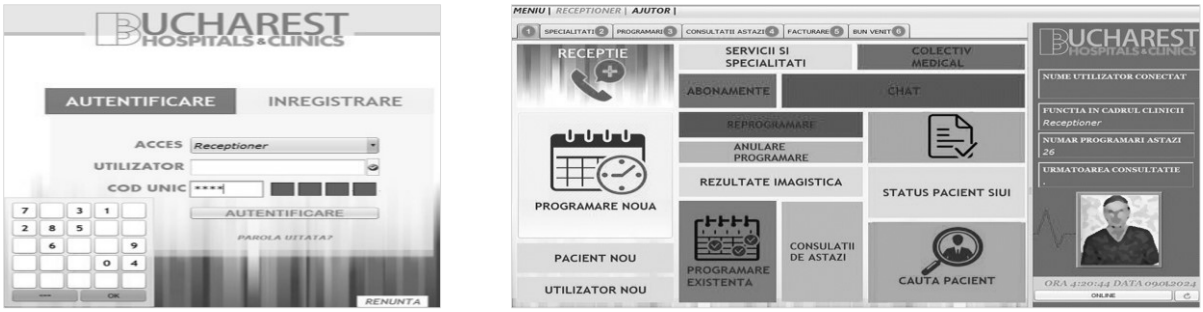

Figure 8. Desktop application interfaces: a) login form, b) principal menu for receptionist user-type.

All consultations are documented and stored in the patient's medical record to provide medical staff comprehensive medical information for accurate diagnoses, presented in Figure 9a. Authorized medical professionals may access these records. The doctor selects the patient from the list and opens the consultation form, which is customized for different medical operations such as consultation, investigation, collection of samples for medical analysis, etc. Detailing a patient leads to the display of a form with complete personal data, assurance status, and vital medical data such as blood group, RH and major health problems. To complete medical documents, such as the prescription – list of medicines and diagnoses are loaded in the application, being provided fields to facilitate completion of these documents. In addition, the interpretation of medical analysis contains specific application fields, for bringing to light the results outside normal ranges.A medical investigation contains specific fields such as interpretation of results, used substances, etc; the form for investigations is shown in Figure 9b. The administration of medical imaging is efficiently managed through a specialized interface, enabling integration with DICOM imaging or other formats, as shown in Figure 9c.

The medical data recorded are also stored separately and in an anonymized manner. This includes the patient's symptoms, diagnosis, and imaging results labeled with the related diagnoses. ML and DL analysis are used to offer diagnoses to other patients with similar pathologies, based on previous experience and available medical data. For testing, various datasets from online medical sources, including DICOM standard medical imagining, were loaded into the application, running multiple algorithms. Oracle automatically provides functions to anonymize OrdDicom files so that they can be safely used for research purposes [35].

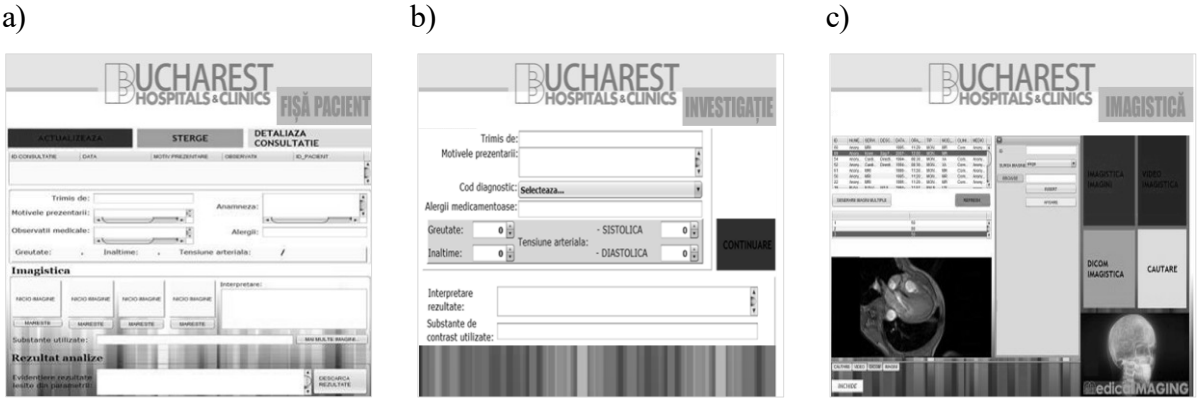

Figure 9. Desktop application interfaces: a) patient record, b) investigation, c) medical imaging.

The medical staff selects the relevant symptoms of the patient from a predetermined list. These symptoms, along with other clinical and personal data (age, weight, height), are input into an ML framework. Algorithms analyze this information to identify patterns and correlations with various medical conditions. An ML classification model from the Weka library is integrated into the application. This model was trained with a data set obtained from an online repository and helps to classify new data, represented by the symptoms of the new consulted patient and predict belonging to a certain class, represented by the potential diagnosis. This framing is done according to the input characteristics and the relationships learned from the training data. The evaluation of the models is carried out by applying standard performance metrics by testing on samples from the initial dataset. The training data set is a general one, addressed to family medicine, and for other medical specialties will require training with specific data or models. This process helps in the assessment and treatment planning; these potential diagnoses serve as guidance for the medical staff, who make the final diagnosis, considering any additional clinical factors. In the end, the data resulting from the consultation becomes a training source for establishing ML models.

The classification procedure is performed similarly for medical analyses and for the data obtained from wearable devices, using specific datasets for model training. These are represented, for medical analyses, by measurements of parameters for usual analyses such as glucose, cholesterol, triglycerides, hemoglobin, etc., and for wearable devices and fitness data, by heart rate, oxygen saturation, number of steps, etc. Classification algorithms are trained on these datasets to identify patterns and correlations, respectively, warning signals that can lead to early diagnosis. The DICOM images, obtained from radiographs from an online repository regarding a specific pathology, were converted into a format supported by the Weka – WekaDeeplearning4j extension, namely JPEG. Thus, the video-imaging to be analyzed goes through pre-processing (scaling, resizing, and normalization) to ensure the consistency and quality of the data. The training model is built using DL algorithms, more precisely neural networks suitable for image analysis, checking the performance evaluation metrics on test samples. This process of creating the model is used to analyze and interpret images obtained from new patients who present for consultation; in the test environment, simulations were made on data from online sources.

The database was built following the structure from the point of view of the entities, designing 40 tables with related relationships. The database uses the Oracle 12c Database Management System. Specific procedures for interacting with multimedia elements such as OrdImage, OrdVideo, and OrdDicom, from the OrdSys library, have been defined. Thus, the database facilitates the inclusion of medical imaging in the constitution of patients' medical files [35].

In Table 2, the main functionalities implemented at the desktop and mobile application level are detailed, together with the technologies used, the method of implementation in the backend, and the integrated models.

The Android mobile application integrates Java Files, which implements the backend part of the main functionalities of the application, and contains main source code. This manages the responses generated following API requests, deserializing and transforming JSON data into Java objects, making them available at the mobile application level. In addition to this type of file, other dependencies are added. The permission part, and the API used (version 33) are contained in the *Android Manifest*. In this, permissions were defined for "INTERNET" allowing the application to open network sockets [36]. "CALL_PHONE" access was defined to allow the application to use the phone to make calls, useful for direct calls to medical units. "WIFI_STATE" and "NETWORK_STATE" were defined for access to the state of the WI-FI and mobile data networks. When the connection to the Internet is lost, the user is notified because requests require an active connection. "BODY_SENSORS" was defined for access to fitness data measured by the mobile device, "ACTIVITY_RECOGNITION" was defined for recognizing the types of physical activities, "ACCESS_FINE_LOCATION" was defined for recognizing the distance and speed of physical activities, and for locating the patient's position relative to the medical units. "WRITE_CALENDAR" was defined to save the appointment in the patient's calendar. The other dependencies store the resources and the graphic part of the application (Res), such as figures/shapes/colors and icons (drawble and mipmap), the optimized screen format for both smartphone and tablet, and for portrait and landscape orientation (layout), the personalized menu for patients (menu) and constants utilized at the application level (values), and ensures that all elements needed by the project are available and that all dependencies and plugins are assembled (Gradle Script).

Table 2. Details of the functionalities and models integrated into the application setup (continued on pp.540-542).

Main Functionalities	implemented in the version:		Technologies		Integrated Models
	Desktop (Medical staff)	Mobile (Patient)	Desktop interface	Mobile interface	
Authentification					
Login of medical staff with specific credentials to access the application.	Authentication using credentials.	–	JavaFX for the login GUI.	- Java and multiple dependencies for Android mobile version - login interface.	- Strong password patterns and password encryption; use of hashing techniques to protect against cyber-attacks; - Use of JSON Web Tokens (JWT) for authentication; the server generates a digitally signed token, which contains information about the user and permissions, then are included in the requests to the server.
Login of patients with credentials to access the application.	–	Authentication using credentials. (When the account is created, the approval is done by a medical staff user).			

Table 3. Details of the functionalities and models integrated into the application setup (continuation from p.539, continued on pp.541-542).

Patient Medical Records					
Management of patients' personal data.	Inserting / viewing/ modifying/ deleting patient data depending on the access level of the medical staff.	- Inserting / viewing/ modifying personal data.	- JavaFX for intuitive and easy-to-use GUI (Interactive graphic interfaces are presented through which medical personnel interact with medical data, imaging results and other medical investigations of patients).	- Java and multiple dependencies for Android application development; - SQLite for patient-level persistent data storage - centralized reporting; - Google Fitness SDK for integrating and monitoring fitness data.	- Intuitive and user-friendly graphical interface; - Sensitive data security model; - Medical history management; - Notification for appointments; - Fitness data monitoring.
Management of personal and medical documents regarding the patient.	- Uploading internal documents; - Viewing/ modifying/ deleting/ existing documents depending on the access level.	Uploading personal external documents (For example, medical results from other medical institutions, proof of insurance, etc.)			
- Management of medical records, including vaccination schedule, blood group, allergies, etc.	- Uploading/ viewing the medical situation of patients depending on the access level.	- Viewing personal medical history.	- Oracle 12C for centralized data storage; - Oracle Multimedia extension for mulitmedia file management (medical Images / Video/ Dicom); - API requests of the following type are made: *POST/records* *GET/records/{patient_id}* *PUT/records/{patient_id}* *DELETE/records/{patient_id}*		
- Management of fitness information from wearable smart devices.	- Viewing summary reports on parameters from semi-medical devices.	- Synchronization of data from wearable devices.			
Centralized Medical Units and the Medical Program					
-Management/ interactive visualization of medical units.	- Updating and managing data related to medical units, departments, specializations, medical services, and medical schedules.	- Interactive visualization of medical units (including positioning on GIS maps), specializations and medical programs.	- JavaFX for intuitive and easy-to-use GUI.	- Java and multiple dependencies for Android application development; - Google Maps SDK for displaying medical facilities on the map.	- Interactive interface for managing and viewing medical units; - Effective search and filtering of medical units according to the name of the unit or specialization; - GIS system integration for locating medical facilities;
- Searching and filtering medical facilities by specific criteria.	-	- Selection of the option depending on the specifics of the pathology and availability			

Table 4. Details of the functionalities and models integrated into the application setup (continuation from pp.539-540, continued on p.542).

	-	in the medical schedule.	- Oracle 12C for centralized data storage; - API requests of the following type are made: *POST/medical_units* *GET/ medical_units/{unit_id}* *PUT/ medical_units/{unit_id}* *DELETE/medical_units/{unit_id}*		- Optimized management of the medical schedule.
- Defining the medical staff schedule for providing medical services.	- Updating and managing the schedule for consultations, laboratory analyses, radiological investigations, medical interventions, recovery programs, etc.	-			
Medical Appointments and Consultations					
- Centralized manage-ment of appointments and consultations.	- Inserting/ viewing/ updating/ deleting appointments.	- Request to change an appointment.	- JavaFX for intuitive and easy-to-use GUI.	- Java and multiple dependen-cies for Android application develop-ment.	- Scheduling and consultation management; - Synchronization, optimization, and real-time updating of schedules between applications; - Notifications to confirm and remind appointments.
- Appointment confirmation and reminder notification.	- Viewing notifications regarding new patient appointments.	- Viewing notifications about personal appointments.	- Synchronization and real-time updating of schedules between the desktop and mobile application; - Oracle 12C for centralized data storage; - API requests of the following type are made: *POST/appointments* *GET/appointments?date=YYYY-MM-DD&patient = {patient_id}&unit={unitid}* *PUT/appointments/{appt_id}* *DELETE/appointments/{appt_id}*		
- Patient examination according to the schedule.	- Opening the consultation and offering a diagnosis, and providing prescriptions, treatments, etc.	-			
Medical Data Analytics					
- Diagnosis based on the patient's symptoms or medical analysis results and suggestions provided by pre-trained models.	- Visualization of potential diagnostics based on suggestions offered by the application.	-	- JavaFX for intuitive and easy-to-use GUI--integrating suggestive graphic represen-tations to figure the results from the most common sensors integrated in Google Fit	- Java and multiple dependencie s for Android application developmen t. - Google Fitness SDK for integrating and monitoring fitness data;	- Medical data analysis and diagnosis; - Medical reports and recommendations generation; - Remote physical activity and health monitoring; - Sharing health data with the family physician.
- Diagnosis based on medical imaging and suggestions		-			

Table 5. Details of the functionalities and models integrated into the application setup (continuation from pp.539-541).

Medical Data Analytics					
offered by pre-trained models.	offered by the application.		synchroni-zable mobile devices.	- SQLite for patient-level persistent data storage--centralized reporting.	
- Diagnosis based on data from patient wearable devices.	- Visualization of potential alarm signals in patients' fitness scores based on suggestions provided by the application.	- Loading data from devices connected to Google Fit and synchronized with the application.	- Oracle 12C for centralized data storage; - In the backend, machine learning and deep learning algorithms are implemented for modeling models to facilitate medical predictions and specific libraries for processing and analyzing medical images.		
Remote discussions between patients and medical staff					
- Real-time communication between patients and medical staff.	- Synchronous communication with patients through chat.	- Synchronous communication with the medical staff through chat.	- JavaFX for intuitive and easy-to-use GUI.	- Java and multiple dependencies for Android application development.	- Real-time communication between patients and medical staff; - Real-time communication between medical staff.
- Real-time communication between medical staff.	- Synchronous communication with other doctors through chat.	-	- Firebase for real-time chat management and notifications.		
Patient Feedback and Medical Units Review					
- Providing feedback on medical services.	-	- Giving feedback regarding: professionalism of the medical team, well--being generated as a result of the treatments received, and the facilities within medical unit.	- JavaFX for intuitive and easy-to-use GUI.	- Java and multiple dependen-cies for Android application develop-ment.	- Collecting and managing feedback effectively; -Feedback analysis and reporting.
- Collecting and managing feedback effectively.	- Analyzing and reporting feedback to improve medical services.	- Viewing reviews provided by other patients.	- Oracle 12C for centralized data storage.		

THE CONTRIBUTIONS OF THE DEVELOPED SOFTWARE APPLICATION

The informatic solution simulates the functionalities from the point of view of medical specialists and patients to observe what facilities can be made available at the city level. From the perspective of *medical staff* and *sanitary units*, implementing a solution such as the proposed one can create a centralized solution at the city level. Thus, it will be possible to track the availability of appointments for both outpatient consultations and hospitalizations at any time. This will enable the definition of medical services available to patients within medical specialties, the distribution of doctors by specialty and services, and the list of investigations and laboratory analyses available in the medical unit. Every doctor with access to the Desktop version of the computer software, authenticated with a specific account, will be able to interact with patients requesting medical services. They will also be able to asynchronously interact with patients who are not physically present in the office by viewing reports generated based on information provided voluntarily. These data can be either received from mobile devices carried by them, or uploaded manually to the platform. These can be the results of medical tests, or various fitness parameters that can be easily measured at home, such as blood pressure, heart rate, blood glucose level, weight etc. Devices synced through Google Fit or other native SDKs on a smartphone can be connected to the application to transfer data automatically, either smart medical devices or semi-medical wearable gadgets. This minimal information can help with the prevention side, being able to early signal the appearance of some health problems.

During consultations and investigations, medical personnel will be able to provide diagnoses based on the available patient's complete medical history, and will be updated with the results of the new consultations. Medical analysis data and output from medical imaging equipment, such as images, video sequences, and DICOM imaging, will also be incorporated into patient records. These data are stored in an Oracle 12c database with multimedia capabilities. The database is natively compatible with the DICOM imaging standard and allows metadata for images and videos. Interaction with the application guarantees the security of the data exposed through REST requests. Anamnesis, symptoms, and diagnosis data are also stored separately and anonymously to become part of the learning component. This enables the automatic generation of presumptive diagnoses through ML (for text-based and numeric analysis) and DL (for imaging analysis) algorithms to assist with the final diagnosis that is formulated by medical specialists.Within the application, a chat server is also being developed for the collaboration of the medical team to address professional issues. This is accessible at the local level of each medical unit and also allows connecting with doctors from other units, which can facilitate interaction between specialists.

From the *patient's* perspective, the software application provides access at any time to the list of all enrolled medical units and exposed through the REST service. Therefore, a patient can use a smartphone device with the Android OS app to access a variety of information, including positioning of medical units via Google Maps SDK and contact information for those. Application exposing clinical specialties and medical services provided by specialists, family physicians, dentists, assistants, etc. The application includes data on ambulatory care, hospitalization, interventions, specialized investigations, and laboratories. Once a user's credentials have been created and approved within the application, they may then schedule one of the medical services offered by the desired medical unit. Patients can read reviews from other patients regarding various aspects in the review section of the medical assistance units. This includes appreciation of the professionalism of the medical team, the well-being generated as a result of the treatments received, the facilities within the medical unit, and the general impression. They will also be able to provide feedback on these aspects after receiving the medical service. The medical record will be updated after each medical service received, so the

patient will have a history of all the medical information and documents. They will be able to present historical data to other doctors, even those from the private health system.

From the perspective of the management of medical institutions and the HR&Financial staff the application will be able to centralize economic information regarding multiple aspects. These include evidence of medical documents granted by the medical and auxiliary staff and the number of hours worked for salary calculation. They will be able to define the schedule of each doctor separately, considering vacations, the number of overtime hours, etc. They will also be able to generate reports on the billing and settlement of medical services.

With each technological solution implemented in the healthcare system, the city becomes more interconnected with the needs and concerns of its citizens. The developed solution clearly brings significant improvements in patient experience, explicitly targeting the satisfaction of patients' needs. By integrating the analysis of data from the sensors of wearable devices, substantiating diagnosis based on ML and DL analysis, facilitating scheduling by listing the availability of the entire network of medical facilities in the city, as well as exposing the feedback provided by patients (which helps both medical facilities to implement improvements where deficiencies are identified, and for citizens to make informed choices about the doctor who meets their needs), the city becomes a smarter place and more responsive to its public health demands. By promoting a citizen-centric approach and using technology to improve the quality of life, cities can confidently aspire to the status of smart cities that focus on increasing well-being and health.

CONCLUSIONS

From a global perspective, medical systems are becoming increasingly clear as complex systems, involved in an intricate network of interdependencies. To better understand this complexity, the flows from the Municipality of Bucharest, were taken as a case study. Here, there are advanced IT implementations that manage the interaction for various operations between medical service providers and patients. However, there is a constant need to identify solutions to maximize its potential and enhance its accessibility and functionality in the support of the citizens. The integration of e-healthcare technologies, wearable medical monitoring devices, centralized scheduling facilitation, the widespread use and management of personal health data recording, and the use of ML and DL technologies for the automatic processing and analysis of medical data is an important approach for the development of smarter and more resilient communities. A solution like this can also adapt to the specific needs identified during the COVID-19 pandemic.

The proposed application offers medical professionals a streamlined method of accessing comprehensive patient data, thereby aiding the diagnostic process. Facilitates an interdisciplinary medical approach based on historical data from patients' electronic files. In addition, the integration of reports sent by the patients – the transmission of medical values through the mobile application voluntarily, either from the sensors or voluntarily distributed – can offer a preventive and monitoring character, providing a more personalized medical care. Although wearable devices serve especially for informative purposes, the extracted data can be interpreted by the attending physician, creating a more accurate picture of the patient's state of health. The focus of the application is centered on the patient, being oriented to current needs, and can be adapted for scaling to real-world requirements in the context of a smart city. Being a patient-oriented solution, the aim is to simplify the process of finding a medical service provider at the centralized level of the city using the mobile application. These can be scheduled as quickly as possible for consultations, facilitating as well the management of medical documents.

The interfaces, both in the mobile and desktop versions, are simple, and ergonomic, displaying in the foreground only the information necessary for a specific operation. The solution allows users to save time and pay more attention to medical care. Quick data management is facilitated by key-combination shortcuts, logically structured menu bars, and specific work interfaces for each type of user. The software application faces limitations in the case of macro-level implementation. The most important factor being represented by the need for additional levels of data security, being susceptible to cyber-attacks. Another important limitation derives from the values obtained from mobile device sensors. Currently, there is no standardization of wearable devices, with most manufacturers indicating that the measurements taken are for information purposes. The data collected from them requires some filters to reduce anomalies and outliers, which can be generated, including by the incorrect use of wearables; in many cases, the measurements are not performed under optimal conditions. In further studies, approaches to minimize these factors will be explored. However, not all citizens have smart mobile devices and technical knowledge, or agree with the adoption of such technologies. A thorough analysis is necessary to assess the feasibility of implementing such softwares.

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MARKETING ETHICS AND CUSTOMER LOYALTY: THE SERIAL MEDIATING ROLE OF RELATIONSHIP QUALITY AND THE MODERATING ROLE OF VOLUNTARY SIMPLICITY

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ABSTRACT

Although there has been considerable theoretical support outlining a relationship between marketing ethics and customer loyalty, there is limited empirical evidence validating this relationship. This study examines the relationships among perceptions of marketing ethics and customer loyalty in a sample of Turkish consumers. The results demonstrate that marketing ethics is negatively related to customer loyalty. Furthermore, this research investigates the processes through which marketing ethics affects customer loyalty. The relationship between marketing ethics and customer loyalty is sequentially mediated by customer satisfaction and customer trust. On the other hand, this research also investigates whether voluntary simplicity has a moderating role in the impact of marketing ethics on customer satisfaction and customer trust. The results demonstrate that the relationship between marketing ethics and customer satisfaction is moderated by self-sufficiency and intangible life which are sub-dimensions of voluntary simplicity; however, there is no moderating role of planned shopping and simplicity in product which are the other sub-dimensions of voluntary simplicity.

KEY WORDS

marketing ethics, customer loyalty, customer trust, customer satisfaction, voluntary simplicity

CLASSIFICATION

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INTRODUCTION

In today's landscape, characterized by heightened ethical consciousness and intense competition within the service industry, relying solely on price competitiveness has become increasingly challenging for financial institutions. As a result, an increasing number of service marketers recognize the importance of initiating and maintaining lasting relationships with customers [1-4]. This acknowledgment is particularly evident in service sectors characterized by ongoing changes and significant purchase uncertainty. To optimize long-term performance, especially in terms of customer retention and loyalty, firms in the service sector must strive to establish, maintain, and nurture long-term, mutually beneficial relationships with their target customers [5, 6].

In the current competitive market environment, companies seeking to maintain their position and secure sustainable competitive advantages may lean towards a sales-oriented approach. This tendency often arises from pressure from top management to meet predetermined sales targets and sales personnel's goals to meet individual sales quotas. A sales-oriented approach that places sales volume above the consumer's wishes, needs and expectations can lead to an increase in consumer complaints due to preferences being overlooked. Moreover, the relentless pursuit of profit can tarnish a seller's reputation, highlighting the dangers of a narrow focus on sales. Consequently, marketing management aims to engage consumers through various tactics to promote their products and brands. In turn, consumers base their purchasing decisions on both familiar product features and newly introduced offerings. During the evaluation process, consumers may experience negative emotions, including dissatisfaction and angerif they encounter service flaws or product defects. Marketing ethics practices play a crucial role in fostering consumer satisfaction and loyalty by promoting ethical values within companies, thereby building consumer trust and encouraging continued patronage.

Marketing ethics encompasses practices aimed at providing consumers and other stakeholders with personal and/or organizational marketing policies and actions characterized by honesty, transparency, trustworthiness, and accountability. It is also seen as a systematic inquiry that offers guidelines for applying moral standards to marketing decisions, behaviors, and institutions. This systematic examination and adherence to ethical principles encompass various organizational facets, including senior management, senior marketing management, sales and marketing, sales and production, distribution, customer service, advertising, and public relations departments [7]. From the customer's perspective, within an environment where consumer reactions such as dissatisfaction and anger may arise in response to product or service defects, the responsiveness of these specified departments and management tiers to ethical concerns and ethical conduct holds the potential to enhance customer satisfaction and loyalty.

Ensuring customer satisfaction is a paramount concern for businesses, given its pivotal role in fostering customer loyalty and enhancing overall business performance and profitability [8; p.509]. Satisfied customers contribute significantly to loyalty to the business. Customer loyalty typically stems from two motives: either tangible benefits from specific discounts or offers, or emotional attachment or affinity towards a particular product or service. Genuine loyalty depends on fulfilling both the emotional and rational needs of individuals, especially in environments where personal relationships matter [9]. For organizations in the service sector, the message is clear: there is a growing need to leverage novel, non-price factors, such as the ethical conduct of sales personnel, as a means of differentiation to achieve increased revenue growth and improved market share [10]. Within this context, the practice of marketing ethics in the service sector plays a crucial role in the enduring survival of firms, long-term profitability, and sustainable competitive advantage. It facilitates the enhancement of relationships with customers, thereby fostering satisfaction, trust, and loyalty.

The rise of a consumption culture, driven by the proliferation and diversity of products in late 20th-century markets, alongside the widespread use of internet technologies and increased social media engagement [11], has driven individuals away from simplicity, encouraging hedonic behaviors. This shift underscores people's efforts to demonstratetheir societal status, values, and self-worth through consumption, potentially leading humanity down an ethically and environmentally precarious path. In response to escalating consumption levels, the voluntary simplicity lifestyle (VSL) has gained prominence, advocating simplicity and frugality across all aspects of life. This movement champions spiritual richness in the inner realm and material simplicity in the external domain, purportedly enhancing individual life satisfaction and offering an alternative to consumerist society [12].

Aligned with the provided information, the study aims to investigate whether relationship quality mediates the impact of customer perceptions regarding firms' marketing ethics practices on customer loyalty, and whether the voluntary simplicity lifestyle moderates customer loyalty in the Turkish context. Furthermore, the study aims to discern potential disparities in participant perceptions based on gender, income, generation, educational attainment, occupation, monthly income, as well as across six distinct investment incentive regions delineated according to the socio-economic development levels of provinces, considering the implementation of supports within the Investment Incentive System and the sub-business lines within the purchasing entities under examination. To elucidate the primary objectives of the research, the study delves into the constructs of marketing ethics, voluntary simplicity lifestyle, relationship quality (comprising customer satisfaction and customer trust), and customer loyalty.

THEORETICAL/CONCEPTUAL BACKGROUND AND HYPOTHESES

MARKETING ETHICS

An ethical issue or dilemma denotes a discernible circumstance, problem, or opportunity mandating individuals or organizations to navigate a choice between behaviors characterized as right or wrong, ethical or unethical. If an activity engenders a sense of deception or misinformation in consumers, it implies a lapse in marketing ethics [13; p.761]. The discourse on the ethical and social responsibilities of businesses has been ongoing since the late 18th century and the advent of industrial capitalism. Instances of corporate misconduct in the United States, Europe, Southeast Asia, and Australia underscore the potential for significant adverse ramifications on shareholders, employees, investors, customers, and numerous small businesses affiliated with these entities [14-17, 18; p.681]. The literature examining business activities through the lens of social responsibility and ethics attests to the increasing scholarly interest in this domain [19-21].

Marketing ethics has ascended as a pivotal concern for businesses, captivating the attention of both academics and practitioners alike. It necessitates adherence to minimum standards of responsibility in accordance with ethical principles and the execution of marketing activities in a transparent and universally acceptable manner [22-25]. The significance of marketing ethics is underscored by the enduring consumer demand for high-quality products and preference for brands renowned for their social and ethical standing, even at potentially higher prices [26]. Singhapakdi [27] posited in his study that firms espousing an ethical marketing approach and integrating it into their operations yield positive performance outcomes, fostering greater societal acceptance of firms and their products. Gaski [28] delineated marketing ethics as "a set of behavioral and moral norms guiding marketing practices". Marketing ethics serves as a compass for companies, directing them to make ethically sound marketing decisions in their interactions with various stakeholders, encompassing customers, employees, competitors, and

broader society [29]. Alternatively, marketing ethics is characterized as "the systematic inquiry into the application of moral standards in marketing decisions, behaviors, and institutions" [30].

RELATIONSHIP QUALITY

In the service sector, where intense competition and heightened ethical awareness prevail, firms face escalating challenges in competing solely on price. Consequently, service marketers increasingly acknowledge the imperative of cultivating enduring relationships with customers [3, 4]. For instance, in the banking sector, maximizing long-term performance necessitates the establishment, maintenance, and nurturing of long-term, mutually beneficial relationships with target customers [5, 6].

Among the most valuable marketing assets in service-oriented firms are salespeople, whose prowess in marketing is of paramount importance. This is attributable to the pivotal role of interpersonal relationships between sales representatives and customers within the service sector [31]. Salespeople, interfacing directly with customers, wield significant influence over customer satisfaction, loyalty intentions, and the corporate image of the firm. Furthermore, prioritizing the cultivation of successful and high-quality customer relationships elevates salespeople to a strategically critical position in the eyes of customers [32, 33].

Relationship quality, a concept foundational to service marketing, is commonly defined as a constellation of intangible values that augment products or services, engendering an anticipated exchange between buyers and sellers [34]. Dorsch et al. [35] articulate relationship quality as "a high-level construct reflecting the value customers attribute to their relationship with the service provider". Hennig-Thurau and Klee [36] assert that relationship quality denotes the degree of alignment between a relationship and the level of customer needs fulfillment associated with said relationship.

While extant literature generally posits that relationship quality is influenced by three pivotal factors – trust, commitment, and communication – Arnett and Badrinarayanan [37] contend that numerous other factors also impact relationship quality. Moreover, it is suggested that relationship quality may be shaped by one or more relational constructs such as trust, commitment, satisfaction, and communication [6]. Relationship quality is conceptualized as a high-level construct comprising several interconnected dimensions, with satisfaction, trust, and commitment representing critical components [38]. Although the structure and core dimensions of relationship quality vary across empirical studies, the underlying tenet remains that no singular dimension or relational construct can comprehensively capture the overall depth or quality of an exchange relationship [6, 39, 40]. For instance, Morgan and Hunt [41] posit that trust and commitment are pivotal in predicting relationship quality, whereas Palmatier et al. [42] propose that trust or commitment individually can constitute the critical relational construct. Alternatively, some contend that a relationship quality construct integrating commitment, trust, and satisfaction offers the most comprehensive assessment of relationship strength and yields profound insights into performance dynamics [39].

VOLUNTARY SIMPLICITY LIFESTYLE

The term "Voluntary Simplicity" was initially introduced by Richard Gregg [43], as documented in the Indian quarterly newspaper Visva-Bharati [44; pp.9, 45; p.529). According to Gregg [43; p.1], voluntary simplicity encapsulates both internal and external dimensions, embodying determination, sincerity, and honesty in purpose, while eschewing external clutter stemming from the acquisition of superfluous possessions, all in pursuit of life's primary purpose. Furthermore, voluntary simplicity entails the regulation and channeling of energy, desires, and needs, with the aim of leading a higher quality and healthier life. It is also delineated as "the deliberate organization of life for a purpose" [46].

In alignment with Gregg's [43] conceptualization, Elgin and Mitchell [44; p.2] characterize voluntary simplicity as "outwardly simple and inwardly rich", emphasizing its manifestation as the actualization of one's psychological and spiritual potential. Voluntary simplicity is epitomized as "prioritizing what truly matters to an individual, the fundamental aspects of existence" [47; p.12]. The interpretation of "voluntary simplicity" has evolved over time, extending beyond a mere association with "spiritual well-being" to encompass a lifestyle choice marked by consumption limitation and self-governance. Moreover, the contemporary definition emphasizes consumption reduction as a pivotal component of the concept [48; p.150]. Leonard-Barton [49; p.244] defines voluntary simplicity as "the extent to which an individual opts for a lifestyle that maximizes direct control over daily activities while minimizing consumption and dependency".

Table 1. Voluntary simplicity values [44].

Value	Description
Material Simplicity	"Consumption model focused on non-consumption"
Human Scale	"Small-scale institutions and a shift towards technologies"
Self-Determination	"The desire to have more control over personal destiny"
Ecological Awareness	"Recognizing the interdependence of people and resources"
Personal Growth	"The desire to explore and develop the spiritual life"

Elgin and Mitchell [44; pp.4], while addressing globalization alongside universal challenges, idealistic and objective matters, and worldly personal concerns, categorize the motives and values – also identified as the primary sources of motivation driving voluntary simplicity – into five distinct headings: environmental awareness, humanitarianism, self-sufficiency, material simplicity, and personal development.

CUSTOMER LOYALTY

The proliferation of diverse channels facilitating access to customers has led to heightened differentiation and increased competition among businesses, compelling companies to pursue strategic initiatives to thrive in today's fiercely competitive environment. It is widely acknowledged that the sustainability of businesses in such an environment hinges on the establishment and fostering of customer loyalty, which not only facilitates the retention of existing customers but also enables the acquisition of new ones [50]. Customer loyalty is frequently intertwined with firm profitability, making the retention of customers a perpetual priority for firms [51]. The topic of customer loyalty has been extensively explored by various scholars and researchers aiming to comprehend consumer psychology. Diverse definitions and interpretations of the concept have been posited to enhance understanding and delineate the underlying dynamics. An important aspect of the concept of customer loyalty is its variability based on the type of product and industry under consideration, resulting in the absence of a universally accepted definition [52-54].

According to Lai et al. [55], customer loyalty denotes consumers' propensity to select a specific brand or product owing to perceived satisfaction, high value, and product quality, whereas Öcel [56; p.262] characterizes customer loyalty as the sustained purchase behavior of a product or service fueled by a positive attitude towards it. Oliver [57] defines customer loyalty as the steadfast commitment to consistently repurchase or recommend a preferred product/service in the future, thereby engendering recurrent purchases of the same brand or set of brands notwithstanding situational influences and marketing endeavors. Aaker [58] conceptualizes customer loyalty as a gauge of a customer's allegiance to a brand, elucidating the likelihood of a consumer to switch to another brand or company, particularly in response to changes in price or product features. Given that customer loyalty directly translates into future sales, Aaker underscores its significance as an indicator of brand equity intricately linked with forthcoming profits [58; pp.44-45].

MARKETING ETHICS AND CUSTOMER LOYALTY

Lee and Jin [59] established that customer perceptions of ethical marketing practices indirectly influence customer loyalty. It is asserted that unethical conduct by salespersons may precipitate adverse outcomes for the firm, including customer dissatisfaction, diminished loyalty, and decreased sales and profits [60]. Conversely, Alrubaiee [61] concluded that ethical selling behavior does not exert a direct impact on customer loyalty. Building upon these findings, the following hypothesis is formulated:

H_1: Marketing ethics significantly affects customer loyalty.

RELATIONSHIP QUALITY AND MARKETING ETHICS

Consumers meticulously scrutinize firms' marketing ethics practices due to their prominence as the most visible aspect of a firm's activities and structure, playing a pivotal role in shaping consumer perceptions [62-64]. Extensive research on the subject elucidates various ethical issues in marketing, encompassing product safety, price manipulation, deceptive marketing communications, illicit product placement, child labor, and misleading packaging [6, 65, 66]. Ethical considerations, such as those pertaining to justice and human resource management, significantly influence subjective evaluations of product quality and customers' relationships with the firm [65].

Holden [67] contends that the ethical conduct of salespeople positively correlates with customer trust and satisfaction. Chen and Mau [68] discovered that ethical selling behavior substantially impacts customer trust. Wray et al. [69] assert that perceived marketing ethics practices among financial services customers enhance trust in both the salesperson and the firm. Likewise, several studies suggest that customer trust in salespeople can be cultivated through the honest actions of sales representatives [70] and the avoidance of coercive selling tactics [71, 72]. In a recent study, Lee and Jin [59] identified that ethical issues and practices related to marketing mix elements exert a direct influence on the quality of the customer-firm relationship. Based on the aforementioned insights, the following hypotheses have been formulated:

H_2: Marketing ethics positively affects relationship quality.

H_{2a}: Marketing ethics positively affects customer satisfaction.

H_{2b}: Marketing ethics positively affects customer trust.

RELATIONSHIP QUALITY AND CUSTOMER LOYALTY

Research studies [6, 39, 73] affirm that relationship quality enhances customer loyalty and firm performance by fostering stronger relational ties. Many researchers regard customer trust, a key component of relationship quality, as a precursor to both loyalty and successful relationships [74, 75]. Alrubaiee [61] concluded that trust, an integral dimension of relationship quality, exerts a positive influence on customer loyalty. Furthermore, several studies [41, 76, 77] suggest that customer trust is a primary behavioral determinant of loyalty. It is also posited that trust directly enhances loyalty [41, 76, 78], as it mitigates perceived risk and vulnerability in the relationship, fostering greater commitment [75, 79]. Alrubaiee and Alnazer [6] provide the first empirical support to the literature on the positive impact of high levels of relationship quality on bank customer loyalty. On the other hand, some studies [80, 81] confirm that the consumer-company relationship improves customer loyalty. Establishing a strong consumer-company relationship can play an important role in developing consumer loyalty to a company [82, 83]. Commitment, which indicates the desire to maintain a valuable relationship [84], is expressed as a result of trust and satisfaction [85]. While satisfaction is expressed as positive experiences with a company, it is also expressed as an important factor

that creates emotional bonds that ultimately trigger loyalty [86]. Oliver [54] defines customer satisfaction as an individual's perception of contentment with the service provided, whereas customer loyalty is delineated as a profound commitment to the service provider. Numerous studies in the literature corroborate the existence of a strong relationship between customer satisfaction and loyalty [87-91]. Based on the aforementioned insights, the following hypotheses are formulated:

H_3: Relationship quality positively affects customer loyalty.

H_{3a}: Customer trust positively affects customer loyalty.

H_{3b}: Customer satisfaction positively affects customer loyalty.

THE MODERATING ROLE OF VOLUNTARY SIMPLICITY LIFESTYLE

Kara and Irge [92] discovered that customers' perceptions of voluntary simplicity positively correlate with customer satisfaction and loyalty. Based on this information, the following hypotheses were formulated:

H_{4a}: Voluntary simplicity lifestyle moderates the effect of marketing ethics on customer satisfaction.

H_{4a1}: Planned shopping moderates the effect of marketing ethics on customer satisfaction.

H_{4a2}: Self-sufficiency moderates the effect of marketing ethics on customer satisfaction.

H_{4a3}: Intangible life moderates the effect of marketing ethics on customer satisfaction.

H_{4a4}: Simplicity in product moderates the effect of marketing ethics on customer satisfaction.

H_{4b}: Voluntary simplicity lifestyle moderates the effect of marketing ethics on customer loyalty.

H_{4b1}: Planned shopping moderates the effect of marketing ethics on customer loyalty.

H_{4b2}: Self-sufficiency moderates the effect of marketing ethics on customer loyalty.

H_{4b3}: Intangible life moderates the effect of marketing ethics on customer loyalty.

H_{4b4}: Simplicity in product moderates the effect of marketing ethics on customer loyalty.

MEDIATING AND SERIAL MEDIATING ROLE OF RELATIONSHIP QUALITY

The "Cognitive Dissonance Theory" posits that individuals experience psychological tension when their behavior conflicts with their beliefs, motivating them to seek consistency between their thoughts and actions [93]. Consequently, it is argued that discrepancies between expectations and actual purchases may lead to cognitive dissonance among customers, resulting in post-purchase discomfort [94]. Marketing ethics practices, potentially contributing to pre- and post-shopping tensions, are suggested to enhance customer satisfaction and loyalty [60, 95]. Post-purchase dissonance and tension may diminish with the quality of the firm-customer relationship (e.g., satisfaction and trust), fostering positive changes in consumer attitudes and behaviors, thereby bolstering repurchase behavior and loyalty [96; p.167]. Consequently, the role of marketing ethics in fostering positive consumer-firm relationships has gained prominence [97, 98]. In this context, while negative perceptions of firms' marketing ethics practices may initially prompt disloyalty by causing customer tension, they may

subsequently mitigate disloyalty as the firm enhances satisfaction, trust, and overall relationship quality.

Roman [10] concluded that ethical marketing behavior positively impacts customer satisfaction, trust, and loyalty. Chen and Mau [68] and Hansen and Riggle [33] suggested that customer trust in salespersons mediates the relationship between marketing ethics practices and customer loyalty. Lee and Jin [59] found that customer-firm relationship quality mediates the effect of ethical practices related to marketing mix elements on customer loyalty. Alrubaiee [61] concluded that trust, representing relationship quality, mediates the effect of ethical sales behavior on customer loyalty through commitment. Based on this information, the following hypotheses were formulated:

H_5: Relationship quality mediates the effect of marketing ethics on customer loyalty.

H_{5a}: Customer trust mediates the effect of marketing ethics on customer loyalty.

H_{5b}: Customer satisfaction mediates the effect of marketing ethics on customer loyalty.

H_{5c}: Customer satisfaction positively affects customer trust.

Moreover, as overall customer satisfaction reflects a company's consistency in fulfilling promises, it contributes to gaining customer trust [99]. Schirmer et al. [85] found that trust fully mediates the effect of highly educated customers' satisfaction on loyalty. Ou et al. [100] observed trust mediating the effect of customer satisfaction, under the relationship quality construct, on customer engagement and loyalty. Similarly, Ou et al. [100] identified customer satisfaction and trust, within the relationship quality construct, as mediators in the impact of ethical sales behavior on loyalty. Thus, the following hypothesis was formulated:

H_{5d}: Customer satisfaction and customer trust sequentially mediate the effect of marketing ethics on customer loyalty.

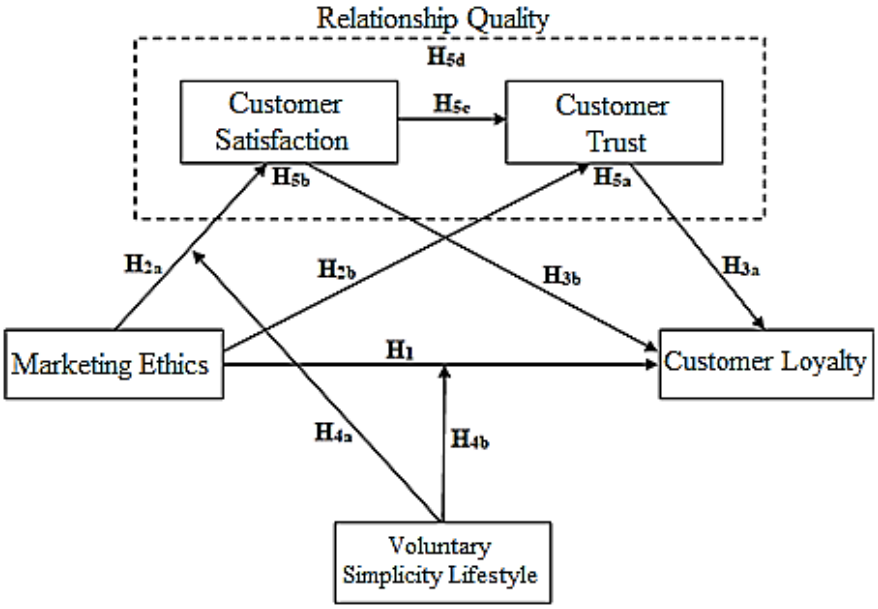

Figure 1. Overview of the hypothesized model

METHOD

THE SAMPLE

The research covers concepts related to marketing ethics, customer satisfaction, customer trust, customer loyalty, and voluntary simplicity lifestyle. The primary population of the study comprises customers in Turkey who have engaged in service sector transactions. The research

sample, on the other hand, comprises individuals who have conducted transactions within specific sub-business lines of the service sector, representing a cross-section of Turkey. The determination of the service sector and its sub-business lines as the focus of the study is based on existing literature, particularly the work of Arslanhan and Çiçek [101]. Their findings show that ethical values and codes, as measured by the marketing ethics scale, predominantly emerge in the sub-business lines of the service sector. The study conducted by Arslanhan and Çiçek [101] was also used to determine certain sub-business lines in the service sector.

A combination of quota sampling and convenience sampling methods were used to ensure both accessibility and cost-effectiveness in data collection. Quota sampling was used to select a predetermined number of participants from each region, while convenience sampling was used to select additional participants. Data collection was conducted through face-to-face and online surveys.

In determining the study sample, quota sampling methods were used to select the provinces within the six regions summarized in Figure 15. These regions were identified based on the socio-economic development levels of provinces, as determined by the "Investment Incentive Practices" system administered by the Republic of Turkey Ministry of Industry and Technology – General Directorate of Incentive Implementation and Foreign Investment. Population data for the provinces were obtained from the population distribution table for 2020 published by the Turkish Statistical Institute (TurkStat) on its website [102].

In this study, the sample size determination utilized the method advocated by Kline [103]. Kline [103] suggests that a sample size of 200 individuals generally suffices for extracting reliable factors, which can be reduced to 100 when the factor structure is concise and evident. However, it is emphasized that employing a larger sample would yield more precise outcomes. Kline [103] recommends maintaining a subject variable (item) ratio of 10:1 when establishing sample size, yet allows for reduction while emphasizing a minimum ratio of 2:1. Accordingly, the research adhered to Kline's guideline of employing a sample size ten times the number of items during the research process. Consequently, based on the marketing ethics scale with the highest item count (22 items in total), a minimum sample size of 220 was calculated, with each region treated as an independent sample, aiming to recruit at least 1320 participants ($6 \times 220 = 1320$) across 6 regions. Ultimately, the study encompassed 1663 participants.

DATA AND DATA COLLECTION TOOLS

The research data were gathered utilizing the questionnaire technique. The research questionnaire comprised four sections. The initial section aimed to gauge participants' perceptions of the voluntary simplicity lifestyle. Subsequently, the second section included a question devised to identify the specific sub-business line group from which participants recalled their recent detailed face-to-face (in-store) shopping experiences, encompassing aspects such as staff, service provider, and services rendered. The third section encompassed scales assessing marketing ethics, customer satisfaction, customer trust, and customer loyalty. Participants were prompted to respond to these scales based on their shopping encounters within the sub-business line identified in the preceding section. The fourth and final section featured inquiries pertaining to participants' demographic information, including gender, generation, educational attainment, occupation, place of residence, and income level.

The measurement scales for marketing ethics, voluntary simplicity lifestyle, customer satisfaction, customer trust, and customer loyalty employed a five-point Likert-type scale (1 – strongly disagree, ... 5 – strongly agree). Subsequent sub-headings provide details concerning the scales employed in the research questionnaire and their respective sources.

Participants' perception of marketing ethics was assessed utilizing a 20-item scale originally developed by Vitell et al. [104]. This scale has been previously utilized by Yoo and Donthu [105] and adapted for implementation in Turkey by Türkmendağ et al. [106], following explanatory factor analysis. Additionally, Demirgüneş [107] adapted this scale from instruments developed by Chen and Mau [68], Ingram et al. [108], Roman and Ruiz [109], as well as from the scale developed by Levy and Dubinsky [110; pp.57-58], which was applied in Turkey by Varinli and Kurtoğlu [111]. The items comprising the 25-item Marketing Ethics Scale originated from ethical codes promulgated by the American Marketing Association (AMA). These codes were formulated by a committee of both academics and practitioners and then approved by a panel of marketers. Yoo and Donthu [105] used a version of this scale consisting of 24 statements in their study. It is noteworthy that these scales have demonstrated solid reliability and validity through empirical examination.

Özgül [112] adapted a scale for Turkey by using the scales used in the studies conducted by Shama [113] and Iwata [114, 115] to evaluate the degree of voluntary simplicity lifestyle. The scale includes a total of 8 statements consisting of planned shopping, giving importance to the non-material elements of life, choosing simple products and self-sufficiency. In the scales developed on the subject, it has been observed that voluntary simplicity consists of dimensions that have similar meanings, but differs according to the structure and cultural characteristics of the society. Özgül's [112] classification was adopted in the study, both because it was conducted in Turkey and because the dimensions discussed were close to the theoretical definition of voluntary simplicity. The scale in question is a scale with proven reliability and validity.

In the study, satisfaction and trust variables, which are the concepts that form the basis of relationship quality, were used to measure relationship quality. In measuring individuals' satisfaction levels with the services provided, Wang and Lo [116], Cronin et al. [116], Eid and El-Gohary [118] and Oviedo-García et al. [119] and the form used in Turkey by Saylan [120] was used. The reliability of the customer satisfaction scale used in this study has been confirmed. In measuring customer trust, the scale developed by Doney and Cannon [76], which is another indicator of relationship quality, and used in Turkey by Altunoğlu and Saraçoğlu [121], and the scale developed by Kabadayı and Aygün [122] were used. Since each of the scales developed by Doney and Cannon [76] or Kabadayı and Aygün [122] was insufficient to represent all of the specified dimensions on its own, the scale was created by taking expressions from both scales. The customer trust scale used in the research is a scale with proven reliability and validity.

The last part of the research survey contains statements regarding the behavioral and attitudinal aspects of customer loyalty. In measuring customers' behavioral and attitudinal loyalty, the scale developed by Lau and Lee [123] and translated into Turkish by Eren and Erge [124] and Zeithaml et al. [125] and created by Özbek and Külahlı [126] and Baydaş and Uslu [127] by making use of the scales used on the Turkish scale, was used. The customer loyalty scale used in the research is a scale with proven reliability and validity.

FINDINGS

NORMALITY TEST FINDINGS OF THE DATA

In the study, the Kolmogorov-Smirnov Test was used to determine whether the data were normally distributed, and as a result of the analysis, it was seen that the data was not normally distributed ($p < 0,05$). It is stated that observing abnormal data in studies of the abovementioned nature is a common situation. Consequently, skewness and kurtosis values for the variables are presented in Table 2.

Table 2. Skewness and kurtosis values for variables.

Variable	Skewness value	Kurtosis value
Price and Distribution	–0,250	–0,524
Product and Promotion	–0,476	0,190
Information and Contract	–0,273	–0,158
Accuracy	–0,394	–0,114
Honesty	–0,439	0,192
Planned Shopping	–0,759	0,267
Self-sufficiency	–0,664	8,988
Spiritual Life	–0,377	0,092
Simplicity in Product	–0,203	–0,539
Customer Satisfaction	–0,521	0,444
Customer Trust	–0,563	0,399
Customer Loyalty	–0,375	0,301

Upon examination of Table 2, it is evident that the skewness values of the variables do not exceed 3, and the kurtosis values are also below 10. According to the literature, in order to apply parametric tests to the research data, it is imperative for the data to exhibit a normal distribution. For normality testing, it is recommended to utilize the Kolmogorov-Smirnov test for studies with $n \geq 50$ observations and the Shapiro-Wilk test for studies with $n \geq 50$ observations [128]. Regarding the evaluation criteria for skewness and kurtosis values, Kline [129] suggests that skewness exceeding 3 and kurtosis surpassing 10 may indicate a problem, with values exceeding 20 indicating a more severe issue. Therefore, the data in this study are deemed suitable for parametric tests.

The Durbin-Watson d statistic was employed to assess autocorrelation between variables. Autocorrelation refers to the presence of a relationship between successive error term values [130]. Literature generally suggests that d statistics falling between 1,5 and 2,5 indicate acceptance of the assumption of no autocorrelation [131]. As a result of the analysis, the d value was determined as 1,943, which shows that there is no autocorrelation between the error terms of these variables.

Variance Inflation Factor (VIF) method is used to determine whether there is a multi-linear relationship. The diagonal elements of the inverse of the correlation matrix of the independent variables are called VIF. VIF is calculated to determine the degree of relationship of an independent variable with other independent variables [132]. If the VIF value is equal to or greater than 10, it indicates the existence of a multicollinearity problem [133]. When the VIF values were examined in the study, it was determined that all of them were less than 10. Therefore, it was observed that there was no multilinear relationship problem between the independent variables.

RELIABILITY TEST FINDINGS OF THE DATA

In order to determine the reliability level of the research data, Cronbach's Alpha coefficient was calculated using the "Internal Consistency Test" technique. Cronbach's Alpha coefficient takes values between 0 and 1; The higher the coefficient and the closer it gets to 1, the more reliable the scale is interpreted. The coefficient in question can be accepted within the range of $0,6 \leq \alpha < 0,7$. It is considered to have good reliability in the range of $0,7 \leq \alpha < 0,9$ and excellent reliability in the range of $\alpha \geq 0,9$ [134]. Reliability was ensured by calculating the coefficient for each structure. Thus, the results of the reliability analysis for the marketing ethics, voluntary simplicity lifestyle, customer satisfaction, customer trust, and customer loyalty scales employed in the collection of research data are presented in Table 3.

Table 3. Reliability test findings.

Scale	Number of items	Cronbach's alpha
Marketing Ethics	22	0,939
Customer Loyalty	9	0,864
Customer Satisfaction	10	0,946
Customer Trust	6	0,940
Voluntary Simplicity Lifestyle	8	0,693

As observed in Table 3, the reliability analysis yielded Cronbach's Alpha coefficients of 0,946 for customer satisfaction, 0,940 for customer trust, 0,939 for marketing ethics, 0,864 for customer loyalty, and 0,693 for voluntary simplicity lifestyle scales. These coefficients indicate high levels of reliability for all scales, affirming their consistency and stability in measuring the respective constructs.

FINDINGS OF FACTOR ANALYSES

The validity of the scales utilized in the study was assessed through exploratory factor analysis followed by confirmatory factor analysis. The findings of these analyses are outlined further in the text.

Findings of Exploratory Factor Analysis

Initial exploratory factor analysis was performed on the voluntary simplicity lifestyle scale. Table 4 presents the factor names, statement codes, factor loadings, eigenvalues, and variance explained by each factor.

Table 4. Explanatory factor analysis results of the voluntary simplicity lifestyle scale (factor extraction method: Principal component analysis; Rotation method: Varimax. Total variance explained 80,8 %; KMO sampling adequacy: 61,2 %; $p = 0{,}000 < 0{,}001$).

Dimension	Item	Factor Loadings	Variance Explained	Eigenvalue
Self-sufficiency	GSYT3	0,902	21,3	2,622
	GSYT4	0,896		
Spiritual Life	GSYT6	0,899	20,5	1,451
	GSYT5	0,887		
Simplicity in Product	GSYT7	0,890	20,1	1,291
	GSYT8	0,888		
Planned Shopping	GSYT2	0,885	18,9	1,103
	GSYT1	0,817		

Another scale utilized in the study, the Marketing Ethics Scale, underwent explanatory factor analysis. Table 5 presents the findings, including the factor names, statement codes, factor loadings, eigenvalues, and the variance explained by each factor.

As a consequence of the factor analysis, initially, a 3-factor structure emerged. According to Lord [135] and Büyüköztürk [136], characteristics such as a sudden decline in the line graph of eigenvalues after the first factor, a horizontal change in the eigenvalue graph of subsequent factors, and proximity between the eigenvalues of the second and subsequent factors suggest unidimensionality. Given that the difference between the eigenvalues of the first and second factors was approximately 4,7 times, and there was proximity between the eigenvalues of the second and third factors, it was determined that a unidimensional interpretation of the scale would be more meaningful [135, 136]. Consequently, the scale underwent another factor analysis as a single dimension.

Table 5. Explanatory factor analysis findings of the marketing ethics scale (factor extraction method: Principal component analysis; Rotation method: Varimax. Total variance explained: 48,7 %; KMO sampling adequacy: 95,7 %; $p = 0{,}000 < 0{,}001$).

Dimension	Item	Factor loadings	Variance explained	Eigenvalue
Marketing Ethics	PE12	0,835	48,7	9,744
	PE13	0,825		
	PE11	0,814		
	PE14	0,807		
	PE10	0,795		
	PE18	0,788		
	PE17	0,751		
	PE9	0,722		
	PE8	0,713		
	PE15	0,671		
	PE6	0,665		
	PE7	0,657		
	PE19	0,639		
	PE5	0,634		
	PE4	0,626		
	PE16	0,596		
	PE22	0,595		
	PE3	0,590		
	PE21	0,577		
	PE1	0,537		

Subsequent analysis led to the removal of statements coded PE2 and PE20 due to their factor loadings being less than 0,45. This refinement resulted in a unidimensional structure with an eigenvalue of 9,744 and a total explained variance of 48,7 %. The line graph depicting the eigenvalues of the components of the marketing ethics variable is presented in Figure 2.

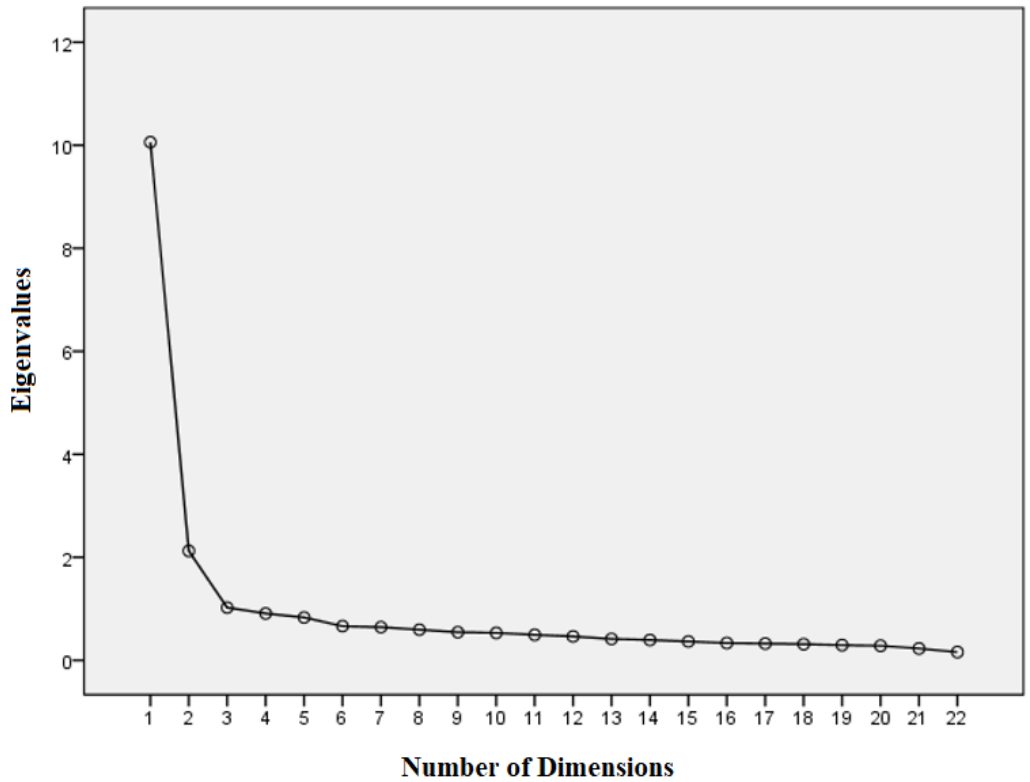

Figure 2. Eigenvalue plot of marketing ethics dimensions.

An explanatory factor analysis was conducted on the customer satisfaction scale, one of the scales utilized in the study. Table 6 presents the findings, including the factor names, statement codes, factor loadings, eigenvalues, and the variance explained by each factor.

Table 6. Explanatory factor analysis results of the customer satisfaction scale (factor extraction method: Principal component analysis; Rotation method: Varimax. Total variance explained: 67,4 %; KMO sampling adequacy: 94,9 %; p = 0,000 < 0,001).

Dimension	Item	Factor loadings	Variance explained	Eigenvalue
Customer satisfaction	MM3	0,856	67,4	6,746
	MM10	0,853		
	MM5	0,842		
	MM8	0,826		
	MM9	0,823		
	MM6	0,820		
	MM2	0,820		
	MM4	0,808		
	MM1	0,796		
	MM7	0,765		

An explanatory factor analysis was conducted on the Customer Trust Scale, another scale utilized in the research. Table 7 outlines the results, including the factor name, statement codes, factor loadings, eigenvalues, and the variance explained by each factor.

Table 7. Explanatory factor analysis results of the customer trust scale (factor extraction method: Principal component analysis; Rotation method: Varimax. Total variance explained: 77,0 %; KMO sampling adequacy: 91,9 %; *p* = 0,000 < 0,001).

Dimension	Item	Factor Loadings	Variance Explained	Eigenvalue
Customer Trust	MG5	0,911	77,0	4,623
	MG4	0,903		
	MG6	0,882		
	MG3	0,875		
	MG1	0,874		
	MG2	0,818		

Explanatory factor analysis was conducted on the Customer Loyalty Scale, one of the scales utilized in the study. Table 8 presents the findings, including the factor names, statement codes, factor loadings, eigenvalues, and the variance explained by each factor.

Table 8. Explanatory factor analysis results of the customer trust scale (factor extraction method: Principal component analysis; Rotation method: Varimax. Total variance explained: 62,2 %; KMO sampling adequacy: 89,8 %; *p* = 0,000 < 0,001).

Dimension	Item	Factor loadings	Variance explained	Eigenvalue
Customer Loyalty	MS6	0,875	62,2	4,357
	MS8	0,867		
	MS9	0,814		
	MS5	0,811		
	MS7	0,784		
	MS1	0,770		
	MS2	0,557		

Findings of Confirmatory Factor Analysis

In the study, the factor structures revealed by the exploratory factor analysis underwent confirmation through confirmatory factor analysis (CFA). Given the diverse treatment of the

voluntary simplicity lifestyle scale in the literature, CFA was initially performed within a single-factor measurement model, followed by examination within first-level and second-level multifactor measurement models. Based on the analysis results, the most compatible measurement model for further path testing was determined.

Scales, owing to their psychometric properties, exhibit varying factor structures. While some scales operate optimally within a single-factor structure, others show improved performance within a multi-factor structure. Consequently, different measurement models are tested using CFA. These models are typically categorized as single-factor, first-order multifactor, and second-order multifactor models. Researchers commonly compare alternative models and strive to identify the most suitable one [137; p.51].

Within the scope of this research, the findings of the confirmatory factor analysis pertaining to alternative measurement models comprising a total of 51 statements, including marketing ethics, customer loyalty, customer satisfaction, customer trust, and voluntary simplicity lifestyle, are presented in Table 9, Table 10, and Table 12. Diagrams illustrating the alternative measurement models are provided in Figure 3, Figure 4, and Figure 5.

First, a single-factor CFA was executed for the research model. The results of the model analysis are delineated in Table 9, with the model diagram depicted in Figure 3.

Table 9. Single factor CFA model results.

Fit indices	Values
CMIN/df	4,565
GFI	0,869
AGFI	0,855
CFI	0,930
NFI	0,912
RMSEA	0,046

Upon examining Table 9, it was observed that, according to the results of the single-factor CFA, although the Comparative Fit Index (CFI) and Normed Fit Index (NFI) values of the model were excellent, and the other goodness-of-fit values were at acceptable levels, the factor loadings of all statements, except for those coded GSYT3 and GSYT4, were below 0,50.

In the second stage, a first-level multifactor CFA was conducted for the research model. The findings of the model analysis are presented in Table 10 and the model diagram is presented in Figure 4.

Table 10. First level multifactor CFA model results.

Fit indices	Values
CMIN/df	4,532
GFI	0,871
AGFI	0,855
CFI	0,931
NFI	0,913
RMSEA	0,046

When Table 10 is examined, according to the first-level multi-factor CFA results, it is seen that the Comparative Fit Index (CFI) and Normed Fit Index (NFI) values of the model are excellent, while the other goodness is goodness-of-fit values are at an acceptable level. Additionally, all factor loadings of the variables are above 0,50.

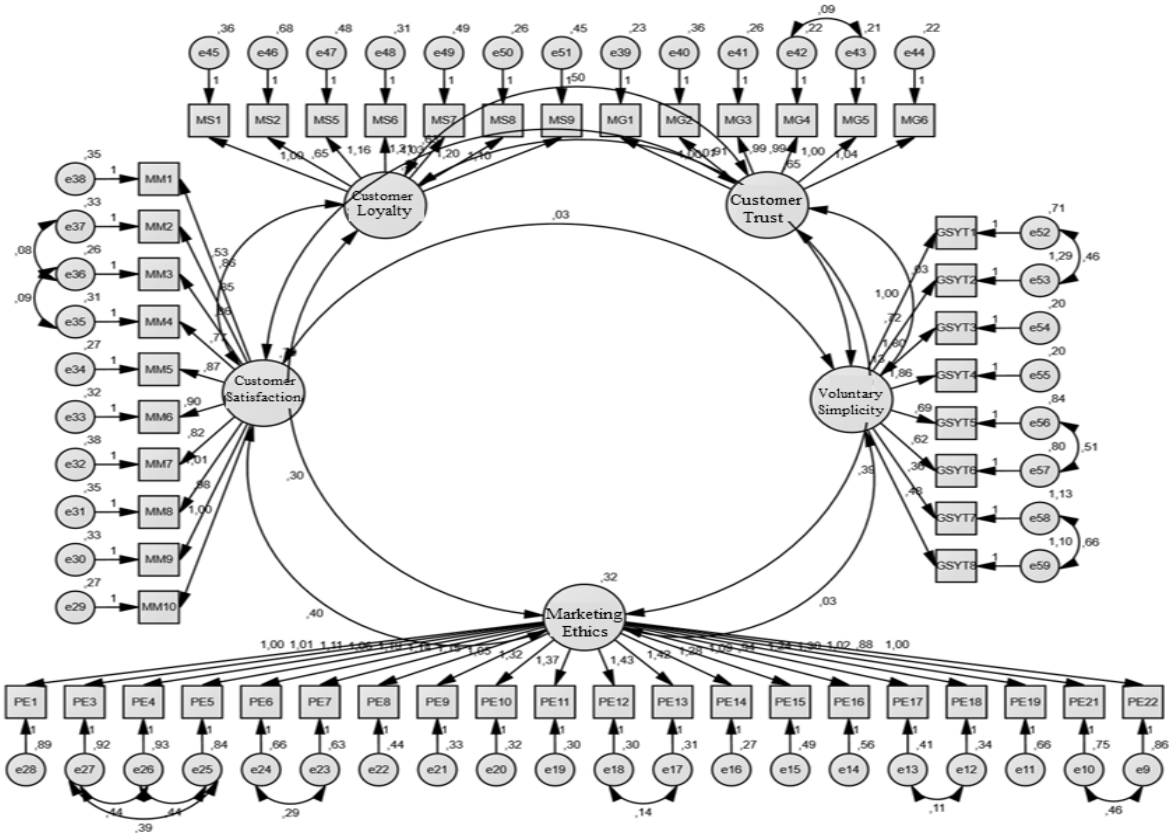

Figure 3. Single factor CFA model diagram.

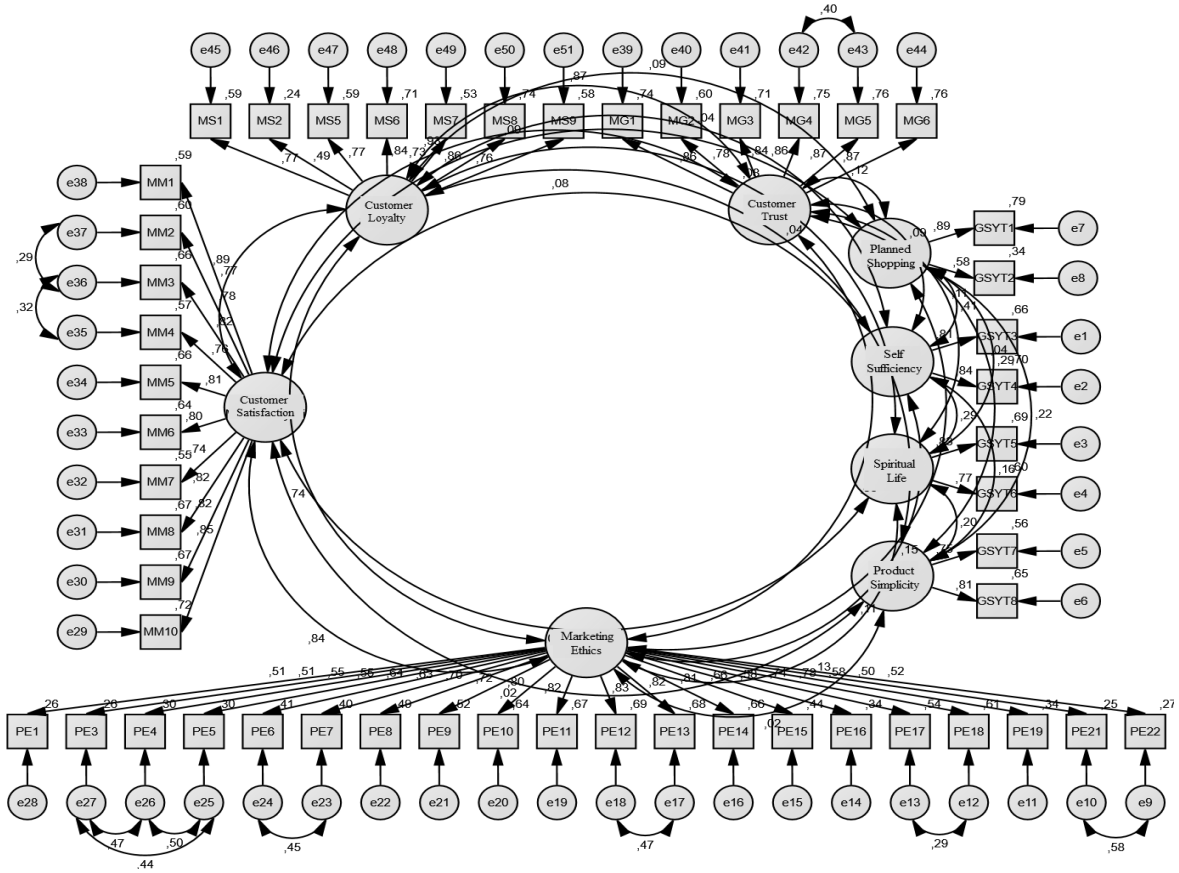

Figure 4. First level multifactor CFA model diagram.

As a complement to the first-level multifactor confirmatory factor analysis, the Composite Reliability (CR) and Average Variance Extracted (AVE) values of each construct were also calculated. Findings regarding the relevant calculations are presented in Table 11.

Table 11. CR and AVE values for constructs.

Faktor	CR	AVE
Marketing Ethics	0,949	0,487
Customer Loyalty	0,919	0,622
Customer Satisfaction	0,954	0,674
Customer Trust	0,953	0,770
Planned Shopping	0,840	0,725
Self-sufficiency	0,894	0,808
Spiritual Life	0,887	0,797
Simplicity in Product	0,883	0,790

When the findings in Table 11 are examined, it is seen that the CR and AVE values of all structures are within acceptable limits.

In the third and final stage, second-level multi-factor CFA was conducted for the research model. The findings of the model analysis are presented in Table 12, and the model diagram is provided in Figure 5.

Table 12. Second level multifactor CFA mresults.

Fit indices	Values
CMIN/df	4,495
GFI	0,870
AGFI	0,856
CFI	0,931
NFI	0,913
RMSEA	0,046

Upon examination of Table 12, it was found that, according to the results of the second-level multifactor CFA, the CFI and NFI values of the model were excellent, and the other goodness-of-fit values were at acceptable levels. Additionally, all factor loadings of the variables were above 0,50.

The measurement model used in the study underwent confirmation through confirmatory factor analysis (CFA) using the AMOS Program. In this context, the maximum likelihood method was employed to assess whether the predicted structures of the scales were supported by the collected research data, utilizing an alternative models strategy. The CFA and comparative model findings are summarized in Table 13.

Table 13. Goodness-of-fit values and comparison findings for the models.

Models	χ^2	df	χ^2/df	GFI	CFI	RMSEA	Model Comparison		
								$\Delta\chi^2$	Δdf
1.Second Level Multifactor	5 393	1200	4,495	0,870	0,931	0,046			
2. First Level Multifactor	5 375	1186	4,532	0,871	0,931	0,046	1 vs. 2	18	14
3. Single Factor	5 482	1201	4,565	0,869	0,930	0,046	3 vs. 1	89	1

As indicated in Table 13, the predicted second-order multifactor model demonstrated the best fit to the data. Based on the findings (χ^2 (1200, N = 1663) = 5393,41; p < 0,001; χ^2/df = 4,495; GFI = 0,870; CFI = 0,931; RMSEA = 0,046), it can be inferred that the scales utilized in the study exhibit discriminant validity.

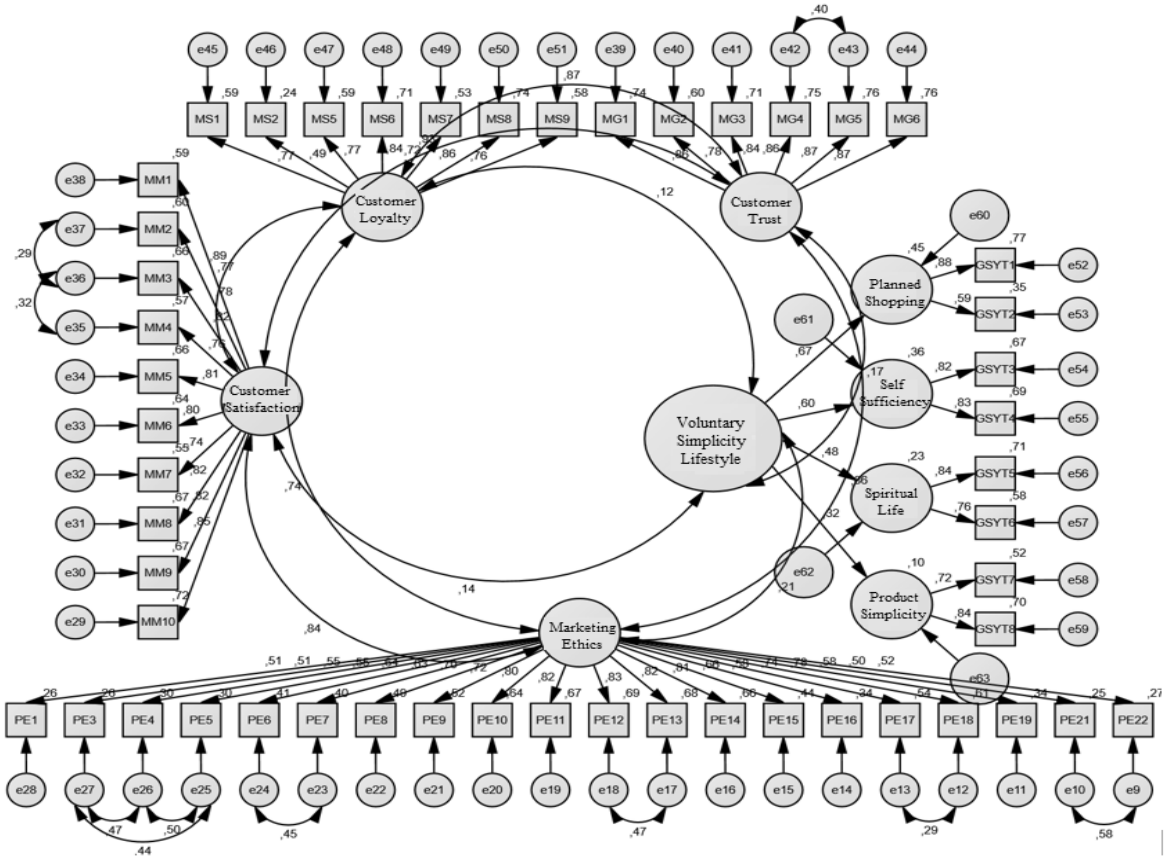

Figure 5. Second level multifactor CFA model diagram,

However, when comparing the χ^2 and df values of Models 1 and 2 (Second Level Multifactor Model and First Level Multifactor Model) using the formulation for calculating the p-value from the χ^2 value as suggested by Brown [138], it was found that the p-value was not significant ($p = 0{,}206 > 0{,}05$). Model 3 (Single Factor Model) was not included in the comparison test due to the low factor loadings of all but two factors, which were less than 0,05. Since it is recommended to use measurement models with at least three statements in analyses conducted with structural equation modeling, Model 3 was deemed inappropriate for further analysis.

Therefore, despite differences in fit values, the lack of statistical significance in the p-value implies that the researcher can make a decision based on theoretical expectations, exploratory factor analysis, or previous research results [137; p.53].Consequently, considering that the voluntary simplicity lifestyle was grouped under four dimensions in the explanatory factor analysis and its four-dimensional form is widely used in the literature, it was decided to select the first level multifactor model (the 2nd model) for subsequent analyses in line with the relevant model.

HYPOTHESIS TEST FINDINGS

To examine the proposed instrumentality, serial instrumentality, and extended relationships in the research model, flexible freedom units were employed. To test relevant errors, 5 000 bootstraps were applied, and confidence interval values of 0,95 or 0,90 were calculated for direct and indirect effect coefficients. As the voluntary simplicity lifestyle encompasses four distinct sub-dimensions, four separate analyses were conducted using the flexible freedom structure for each sub-dimension: Model 1, Model 2, Model 3, and Model 4.

An analysis was conducted to assess the model incorporating the spatial and mutual role of "planned shopping", one of the sub-dimensions of voluntary simplicity lifestyle variability. The moderating variable considered was the variability in strength and direction between

independent and dependent variables. To address moderating effects, Z values of the variables were adjusted to mitigate multicollinearity effects. New interaction variables were created to represent breaks in the independent and moderator variables. These interaction variables were subsequently included in the analysis as independent variables [139; p.224]. The goodness of fit values for analyzed Model 1 are presented in Table 14.

Table 14. Fit indices of path analysis of structural Model 1.

Fit indices	Values
CMIN/df	0,145
CFI	0,99
NFI	0,99
RMSEA	0,00

When reviewing Table 14, it becomes evident that the model exhibits strong performance across absolute, incremental, and parsimony fit indices. The hypothesis test results for the analyzed Model 1 are outlined in Table 15.

Table 15. Hypothesis test findings of structural Model 1.

Hypothesis	Relationships	Direct Effect Coefficient	Indirect Effect Coefficient	Is there effect?
H_{2a}	Marketing Ethics → Customer Satisfaction	**0,785****	-	Yes
H_{5c}	Customer Satisfaction → Customer Trust	**0,622****	-	Yes
H_{2b}	Marketing Ethics → Customer Trust	**0,317****	-	Yes
H_{1}	Marketing Ethics → Customer Loyalty	**–0,046****	-	Yes
H_{3a}	Customer Trust → Customer Loyalty	**0,351****	-	Yes
H_{3b}	Customer Satisfaction → Customer Loyalty	**0,551****	-	Yes
H_{4a1}	Marketing Ethics × Planned Shopping → Customer Satisfaction	0,014	-	No
H_{4b1}	Marketing Ethics × Planned Shopping → Customer Loyalty	0,015	-	No
H_{5b}	Marketing Ethics → Customer Satisfaction → Customer Loyalty	**0,065****	**0,605****	Partial
H_{5a}	Marketing Ethics → Customer Trust → Customer Loyalty	**0,086****	**0,584****	Partial
H_{5d}	Marketing Ethics → Customer Satisfaction → Customer Trust → Customer Loyalty	–0,046	**0,716****	Full

**significant at the level $p < 0,05$

Based on the path analysis results, hypotheses **H_1**, **H_2**, **H_{2a}**, **H_{2b}**, **H_3**, **H_{3a}**, **H_{3b}**, **H_5**, **H_{5a}**, **H_{5b}**, **H_{5c}** and **H_{5d}** were accepted for Model 1. However, hypotheses **H_{4a1}** and **H_{4b1}** were rejected. The path analysis diagram of Structural Model 1 is depicted in Figure 6.

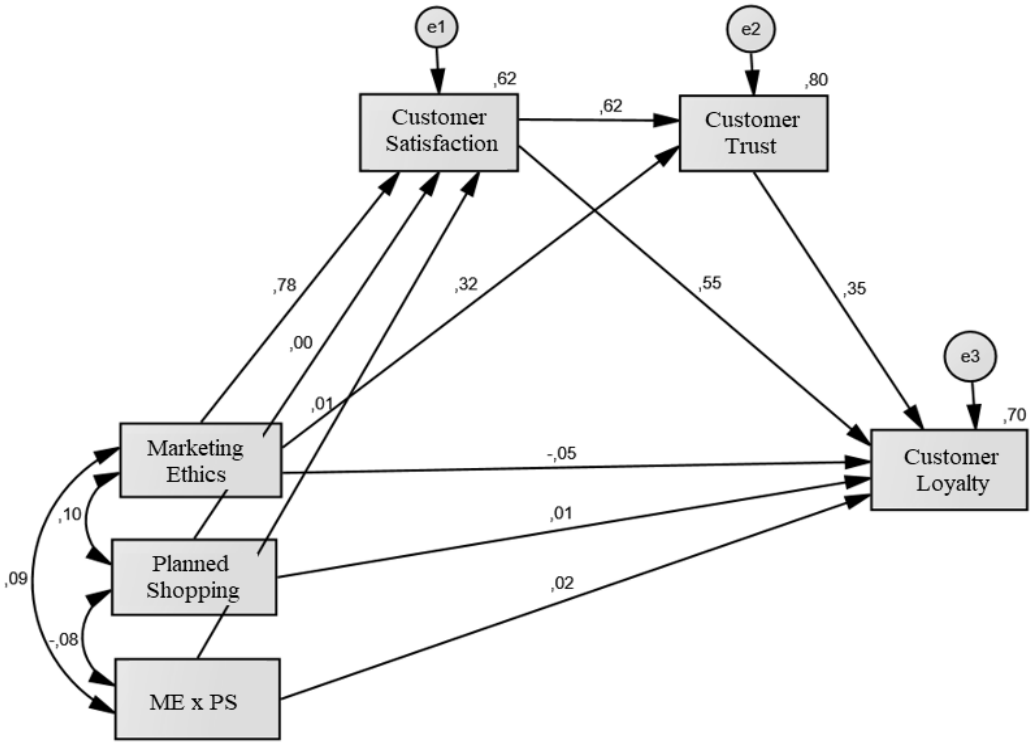

Figure 6. Path model diagram of structural Model 1.

In the study, an analysis was conducted to examine the model where the "self-sufficiency" dimension, another sub-dimension of the voluntary simplicity lifestyle variable, acts as a moderator. The goodness of fit values for the analyzed Model 2 are presented in Table 16.

Table 16. Fit indices of path analysis of structural model 2.

Fit indices	Values
CMIN/df	0,189
CFI	0,99
NFI	0,99
RMSEA	0,00

Upon examination of Table 16, it is evident that the created model demonstrates excellent performance across absolute, incremental, and parsimony fit indices. The hypothesis test results for the analyzed Model 2 are presented in Table 17.

Upon examination of Figure 7, it is evident that the slope of the line at the high self-sufficiency (HIGH S.S.) level is slightly steeper than at the low self-sufficiency (LOW S.S.) level. This discrepancy in slopes indicates that at the high S.S. level, the positive impact of marketing ethics (ME) on customer satisfaction (C.S.) is slightly stronger compared to the low S.S. level.

When Figure 8 is analyzed, it is observed that the slope of the line at the high self-sufficiency (HIGH S.S.) level is slightly steeper compared to the low self-sufficiency (LOW S.S.) level. This discrepancy between slopes suggests that at the high S.S. level, the positive impact of marketing ethics (ME) on customer loyalty (C.L.) is slightly more pronounced than at the low S.S. level.

According to the path analysis results for Model 2, hypotheses **H_1**, **H_2**, **H_{2a}**, **H_{2b}**, **H_3**, **H_{3a}**, **H_{3b}**, **H_{4a2}**, **H_{4b2}**, **H_5**, **H_{5a}**, **H_{5b}**, **H_{5c}** and **H_{5d}** were accepted. The diagram illustrating the path analysis of Structural Model 2 is presented in Figure 9.

Table 17. Hypothesis test findings of structural Model 2.

Hypothesis	Relationships	Direct Effect Coefficient	Indirect Effect Coefficient	Is there effect?
H_{2a}	Marketing Ethics → Customer Satisfaction	**0,780****	-	Yes
H_{5c}	Customer Satisfaction → Customer Trust	**0,622****	-	Yes
H_{2b}	Marketing Ethics → Customer Trust	**0,317****	-	Yes
H_{1}	Marketing Ethics → Customer Loyalty	**–0,045****	-	Yes
H_{3a}	Customer Trust → Customer Loyalty	**0,352****	-	Yes
H_{3b}	Customer Satisfaction → Customer Loyalty	**0,549****	-	Yes
H_{4a2}	Marketing Ethics × Self-sufficiency → Customer Satisfaction	**0,036****	-	Yes
H_{4b2}	Marketing Ethics × Self-sufficiency → Customer Loyalty	**0,030****	-	Yes
H_{5b}	Marketing Ethics → Customer Satisfaction → Customer Loyalty	**0,066****	**0,599****	Partial
H_{5a}	Marketing Ethics → Customer Trust → Customer Loyalty	**0,086****	**0,583****	Partial
H_{5d}	Marketing Ethics → Customer Satisfaction → Customer Trust → Customer Loyalty	–0,045	**0,710****	Full

**significant at the level $p < 0,05$

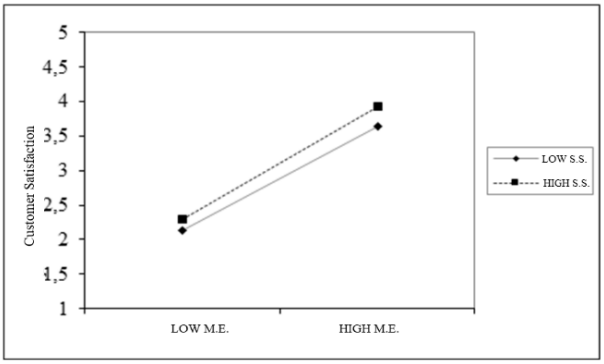

Figure 7. The Effect of marketing ethics (ME) on customer satisfaction for different self-sufficiency (SS) levels.

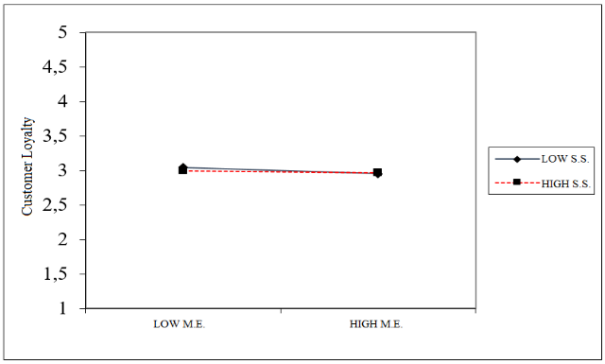

Figure 8. The effect of marketing ethics (ME) on customer loyalty for different self-sufficiency (SS) levels.

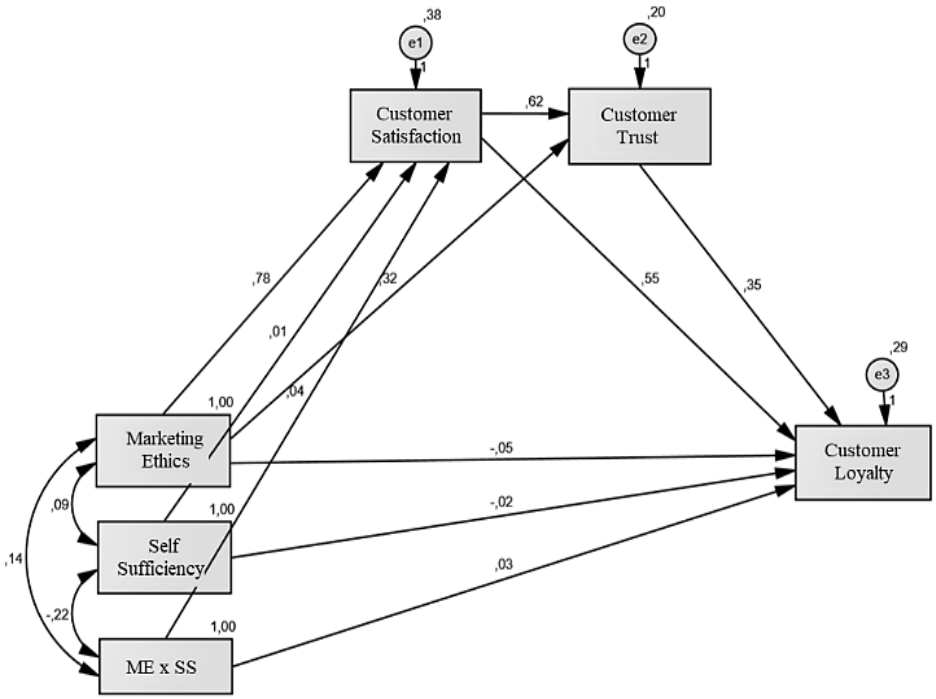

Figure 9. Path Model Diagram of Structural Model 2

An analysis was conducted to test the model in which the "spiritual life" dimension, one of the sub-dimensions of the voluntary simplicity lifestyle variable, is included with its moderating role. The goodness-of-fit values of the analyzed Model 3 are presented in Table 18.

Table 18. Fit Indices of Path Analysis of Structural Model 3

Fit indices	Values
CMIN/df	1,338
CFI	0,99
NFI	0,99
RMSEA	0,014

When Table 18 is analyzed, it is evident that the model is in a very good condition in terms of absolute, incremental, and simplicity fit indices. The hypothesis test findings of the analyzed Model 3 are presented in Table 19.

When Figure 10 is examined, it is observed that the slope of the line at the high spiritual life (HIGH S.L.) level is slightly steeper than at the low spiritual life (LOW S.L.) level. This difference in slopes indicates that at the high S.L. level, the positive effect of marketing ethics (ME) on customer satisfaction (C.S.) is slightly stronger compared to the low S.L. level.

When Figure 11 is examined, it is observed that the slope of the line at the high self-sufficiency (HIGH S.L.) level is slightly steeper than at the low self-sufficiency (LOW S.L.) level. This difference in slopes indicates that at the high S.L. level, the positive effect of marketing ethics (ME) on customer loyalty (C.L.) is slightly stronger compared to the low S.L. level.

According to the path analysis results, hypotheses **H_1**, **H_2**, **H_{2a}**, **H_{2b}**, **H_3**, **H_{3a}**, **H_{3b}**, **H_{4a3}**, **H_{4b3}**, **H_5**, **H_{5a}**, **H_{5b}**, **H_{5c}** and **H_{5d}** were accepted for Model 3. The diagram of the path analysis of Structural Model 3 is depicted in Figure 12.

In this study, an analysis was undertaken to evaluate the model wherein the "simplicity in product" dimension, representing the ultimate sub-dimension of the voluntary simplicity lifestyle variable, assumes a moderating role. The goodness-of-fit values for the analyzed Model 4 are delineated in Table 20.

Table 19. Hypothesis test findings of structural Model 3.

Hypothesis	Relationships	Direct Effect Coefficient	Indirect Effect Coefficient	Is there effect?
H_{2a}	Marketing Ethics → Customer Satisfaction	**0,784****	-	Yes
H_{5c}	Customer Satisfaction → Customer Trust	**0,622****	-	Yes
H_{2b}	Marketing Ethics → Customer Trust	**0,317****	-	Yes
H_{1}	Marketing Ethics → Customer Loyalty	**–0,043***	-	Yes
H_{3a}	Customer Trust → Customer Loyalty	**0,354****	-	Yes
H_{3b}	Customer Satisfaction → Customer Loyalty	**0,546****	-	Yes
H_{4a3}	Marketing Ethics × Spiritual Life → Customer Satisfaction	**0,050****	-	Yes
H_{4b3}	Marketing Ethics × Spiritual Life → Customer Loyalty	**0,034****	-	Yes
H_{5b}	Marketing Ethics → Customer Satisfaction → Customer Loyalty	**0,068****	**0,601****	Partial
H_{5a}	Marketing Ethics → Customer Trust → Customer Loyalty	**0,088****	**0,582****	Partial
H_{5d}	Marketing Ethics → Customer Satisfaction → Customer Trust → Customer Loyalty	–0,043	**0,713****	Full

*significant at the level $p < 0,1$
**significant at the level $p < 0,05$

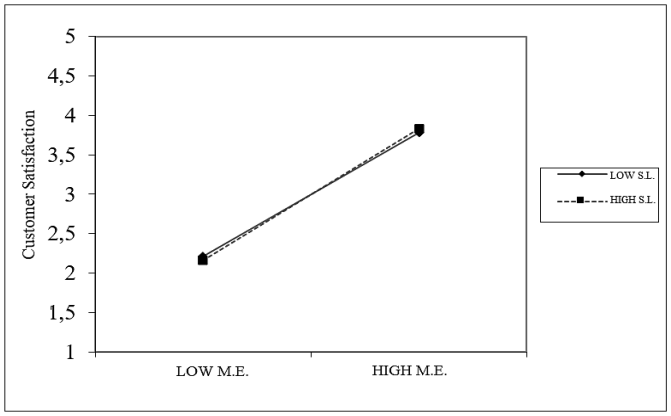

Figure 10. The effect of marketing ethics (ME) on customer satisfaction for different spiritual life (SL) levels.

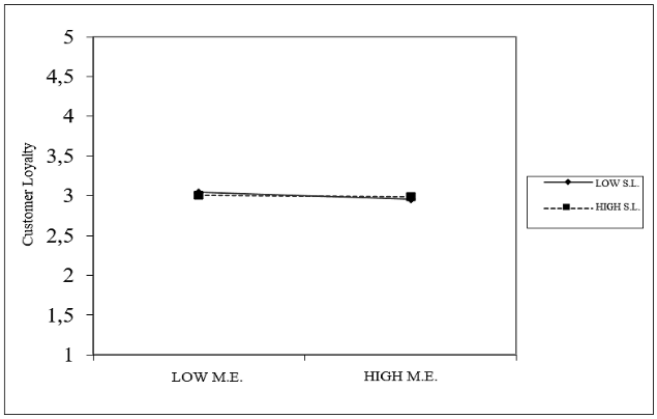

Figure 11. The effect of marketing ethics (ME) on customer loyalty for different spiritual life (SL) levels.

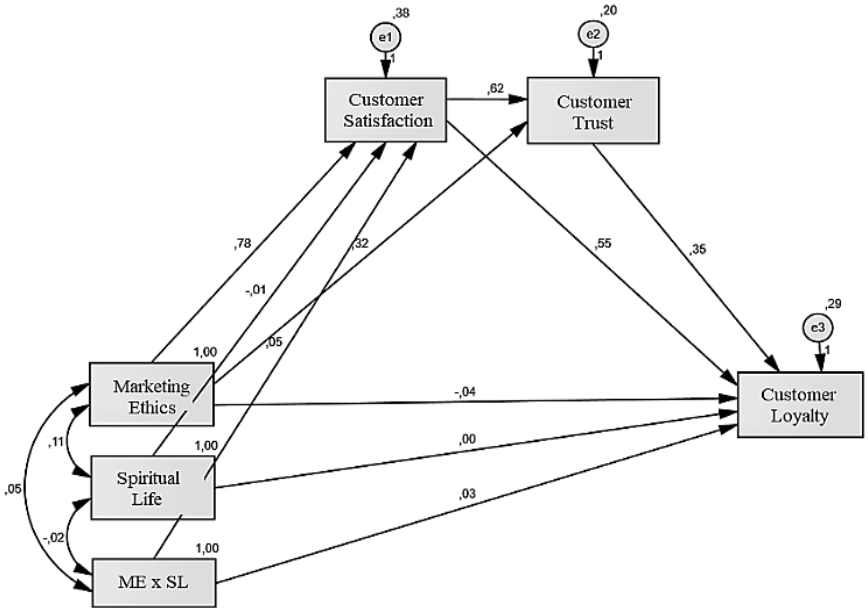

Figure 12. Path model diagram of structural Model 3.

Table 20. Fit indices of path analysis of structural Model 4.

Fit indices	Values
CMIN/df	2,257
CFI	0,99
NFI	0,99
RMSEA	0,028

Upon examination of Table 20, it is evident that the model constructed exhibits favorable conditions in terms of absolute, incremental, and simplicity fit indices. The hypothesis test findings for the analyzed Model 4 are depicted in Table 21.

Table 21. Hypothesis test findings of structural Model 4.

Hypothesis	Relationships	Direct Effect Coefficient	Indirect Effect Coefficient	Is there effect?
H_{2a}	Marketing Ethics → Customer Satisfaction	**0,786****	-	Yes
H_{5c}	Customer Satisfaction → Customer Trust	**0,622****	-	Yes
H_{2b}	Marketing Ethics → Customer Trust	**0,317****	-	Yes
H_1	Marketing Ethics → Customer Loyalty	**–0,044***	-	Yes
H_{3a}	Customer Trust → Customer Loyalty	**0,351****	-	Yes
H_{3b}	Customer Satisfaction → Customer Loyalty	**0,551****	-	Yes
H_{4a4}	Marketing Ethics × Simplicity in Product → Customer Satisfaction	0,013	-	No
H_{4b4}	Marketing Ethics × Simplicity in Product → Customer Loyalty	0,021	-	No
H_{5b}	Marketing Ethics → Customer Satisfaction → Customer Loyalty	**0,067****	**,605****	Partial
H_{5a}	Marketing Ethics → Customer Trust → Customer Loyalty	**0,088****	**0,584****	Partial
H_{5d}	Marketing Ethics → Customer Satisfaction → Customer Trust → Customer Loyalty	–0,044	**0,716****	Full

*significant at the level $p < 0,1$
**significant at the level $p < 0,05$

The path analysis results indicate that hypotheses **H_1**, **H_2**, **H_{2a}**, **H_{2b}**, **H_3**, **H_{3a}**, **H_{3b}**, **H_5**, **H_{5a}**, **H_{5b}**, **H_{5c}** and **H_{5d}** were accepted for Model 4. However, hypotheses **H_{4a4}** and **H_{4b4}** were rejected. The diagram illustrating the path analysis of structural Model 4 is presented in Figure 13.

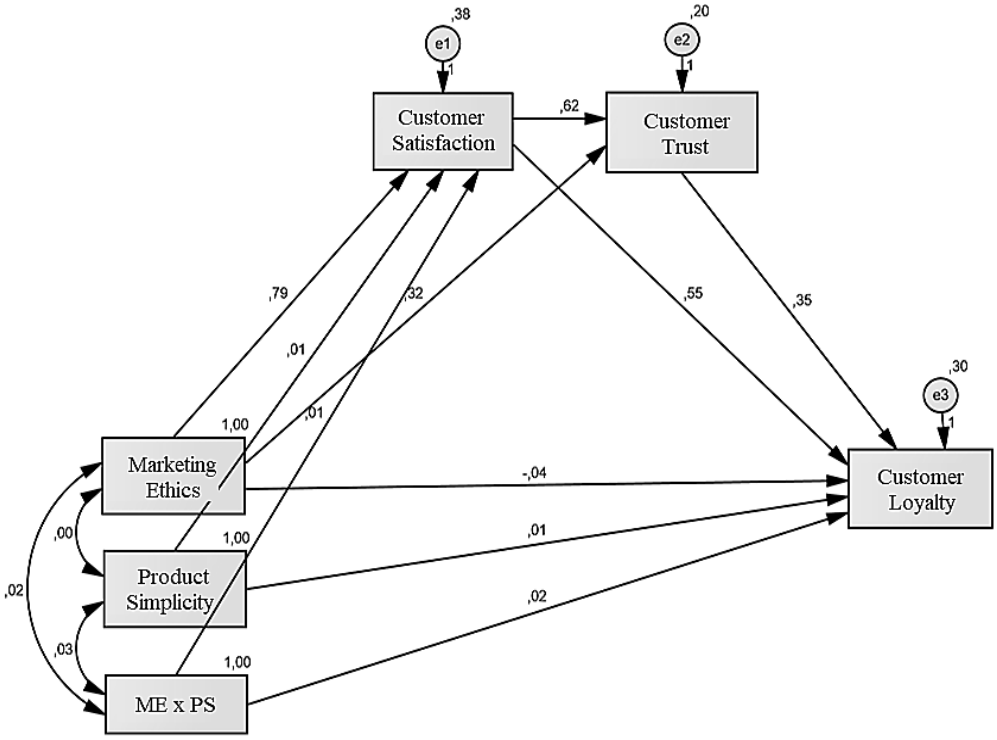

Figure 13. Path model diagram of structural Model 4.

DISCUSSION

The study endeavors to ascertain the mediating and serial mediating roles of customer satisfaction and customer trust in the influence of customer perceptions regarding firms' marketing ethics practices on customer loyalty. Additionally, it seeks to explore whether individuals' voluntary simplicity lifestyle levels moderate the impact of customer perceptions of firms' marketing ethics practices on customer satisfaction and loyalty. Furthermore, the study aims to discern any disparities in participants' perceptions of marketing ethics practices, voluntary simplicity lifestyle levels, satisfaction, trust, and loyalty towards the company based on gender, income, generation, educational status, occupation, monthly income, investment incentive region, and sub-business lines.

Conducted to elucidate the mediating role of relationship quality and the moderating role of voluntary simplicity lifestyle in the impact of marketing ethics perception on customer loyalty, this study contributes to marketing literature as the first empirical endeavor demonstrating the pivotal role of ethical conduct by firms and their personnel in retaining customers. Moreover, it elucidates how such conduct fosters increased customer satisfaction, trust, and loyalty, with voluntary simplicity lifestyle playing an active role in shaping customer perceptions of firms' marketing ethics and subsequent satisfaction and loyalty levels.

Conceptually, the study encompasses marketing ethics, customer satisfaction, trust, loyalty, and voluntary simplicity lifestyle. Although the primary population under investigation comprises individuals residing in Turkey, the research sample consists of individuals who have made purchases from specific sub-business lines within the service sector, representing Turkey more broadly. The study was conducted across provinces within six regions, selected to reflect

the socio-economic development levels and implementation of investment incentive practices by the Republic of Turkey Ministry of Industry and Technology.

The study employed quota sampling to determine regions and convenience sampling to select participants, with data collection facilitated through questionnaires. Explanatory and confirmatory factor analyses were conducted on the gathered data, followed by structural equation modeling and difference analyses to scrutinize the study's hypotheses. Participants' voluntary simplicity lifestyle levels were categorized into four factors: "Planned Shopping", "Self-Sufficiency", "Spiritual Life" and "Simplicity in Product". Notably, marketing ethics, customer satisfaction, trust, and loyalty variables were each grouped under a distinct factor.

The findings reveal that customer satisfaction, a key variable in relationship quality, exhibits a significant and positive partial mediating role in the impact of customers' evaluations of firms' marketing ethics practices on customer loyalty. This outcome aligns with certain studies [10, 59] in the literature while differing from others [107]. Demirgüneş [107] concluded that satisfaction with the salesperson does not have a mediating role in the effect of the salesperson's ethical behavior on repeat purchasing behavior. Similarly, customer trust, another aspect of relationship quality, was found to play a significant and positive partial mediating role in the impact of customers' evaluations of firms' marketing ethics practices on customer loyalty, consistent with prior research.

The evaluations made by customers participating in the research on the marketing ethics practices of companies revealed that customer trust, another variable expressing relationship quality, has a significant and positive partial mediating role in the effect of customer loyalty. In other words, positive customer perceptions towards the marketing ethics practices of companies increase customer trust, and customers whose trust increases become more loyal to the company. The result is similar to some studies in the literature [33, 59, 61, 68]. In addition, the aforementioned result of the study is similar to the result of Demirgüneş [107] that the trust in the salesperson and the company has a mediating role in the effect of the salesperson's ethical behavior on repeat purchasing behavior. The evaluations made by customers who participated in the research on marketing ethics practices of companies revealed that customer satisfaction and customer trust, which are sub-dimensions of relationship quality, have a significant and positive serial mediating role in the effect of customers' loyalty. In other words, positive customer perceptions towards marketing ethics practices of companies firstly increase customers' satisfaction, customers' trust in the company increases as their satisfaction increases, and customers' loyalty towards the company increases even more as their trust increases. In the specified serial mediation relationship, it is seen that the direct effect of customers' marketing ethics perceptions on customer loyalty becomes insignificant. In other words, customer satisfaction and customer trust make the effect of marketing ethics on customer loyalty more significant and higher. It is stated in the literature that general customer satisfaction is effective in gaining customer trust [79, 99]. Schirmer et al. [85] found that trust has a full mediating role in the effect of customer satisfaction on customer loyalty. Finally, Ou et al. [100] found that customer satisfaction and customer trust, which are under the relationship quality structure of sales personnel, have a mediating role in the effect of ethical sales behavior on loyalty. Roman [10] found that satisfaction with core services, satisfaction with the company, and trust in the company have a serial mediating role in customer loyalty to the company from ethical sales behavior. While the above-mentioned result of the study is similar to the results of the studies of Roman [10] and Ou et al. [100], other studies have supported the result. The result of the study differs from the studies of Roman [10] and Ou et al. [100] in terms of the structure of the developed model. Ou et al. [100] and Roman [10] included some of the variables related to the subject (e.g. marketing ethics, customer satisfaction and customer trust) in the model in two separate categories as sales personnel/service received and firm (e.g.

satisfaction with sales personnel/satisfaction with the firm, ethical behavior of sales personnel/ethical behavior of the firm, etc.); in the study conducted, the expressions of the variables were created to cover both sales personnel (firm employees) and the firm, and the variables were included in the model in their comprehensive form. In addition, Ingram et al. [108] revealed that an increase in customer loyalty causes an increase in customers' ethical expectations; an increase in ethical expectations causes an increase in customers' satisfaction. When the obtained results are evaluated together with the results obtained from the study in general, it can be inferred that the interaction in the model of this study (marketing ethics-customer satisfaction-customer trust-customer loyalty interaction) can progress within the framework of a cycle (marketing ethics-customer satisfaction-customer trust-customer loyalty-marketing ethics-... cycle).

In the study, it was revealed that the self-sufficiency and non-material life dimensions, which are sub-dimensions of the voluntary simple lifestyle variable, have significant positive moderator roles, albeit at a low level, in the effect of marketing ethics on customer satisfaction. In other words, while positive customer perceptions of companies' marketing ethics practices increase customers' satisfaction with the company, it has been revealed that the perceptions of self-sufficient and non-material customers about marketing ethics positively affect their satisfaction. No study has been found that directly supports the result in the literature. However, Kara and Irge [92] found that voluntary simple lifestyle has an effect on customer satisfaction as a result of their studies. On the other hand, some studies [65, 67] also state that marketing ethics has an effect on customer satisfaction. Finally, when the studies on the relationship between ethics and spiritual life are evaluated together, it can be stated that customer perceptions of companies' marketing ethics practices are similar to the research result that affects customer satisfaction together with the voluntary simple lifestyle within the scope of logical inference. It has been revealed that the self-sufficiency and non-material life dimensions, which are the sub-dimensions of the voluntary simple lifestyle variable, have significant positive moderating roles, albeit at a low level, in the effect of marketing ethics on customer loyalty. It has been revealed that positive customer perceptions of companies' marketing ethics practices increase customers' loyalty to the company, and the perceptions of customers who are self-sufficient and prefer non-material life towards marketing ethics positively affect their loyalty. In addition, it has been concluded that positive customer perceptions of companies' marketing ethics practices directly reduce customers' loyalty to the company, and the positive perceptions of customers who are self-sufficient and adopt non-material life towards companies' marketing ethics practices positively increase customers' loyalty to the company. Therefore, while the marketing ethics practices of companies actually resulted in a decrease in customer loyalty, the same situation resulted in the opposite for customers who adopted a self-sufficient and non-material lifestyle. Kara and Irge [92] found that a voluntary simple lifestyle has an effect on customer loyalty. On the other hand, some studies [59, 60, 95] also state that marketing ethics has an effect on customer loyalty. When the studies on the relationship between ethics and spiritual life are evaluated together, they are similar to the research result that customer perceptions of companies' marketing ethics practices affect customer loyalty together with a voluntary simple lifestyle within the scope of logical inference. It was revealed that the other dimensions of the voluntary simple lifestyle, planned shopping and product simplicity, do not have a moderating role in the effect of marketing ethics on customer satisfaction and customer loyalty (although marketing ethics has a direct and significant effect on customer satisfaction and customer loyalty). The result obtained is indirectly similar to the literature. While the self-sufficiency and non-material life dimensions are related to the more internal (spiritual) aspect of the voluntary simple lifestyle variable, the planned shopping and product simplicity dimensions are related to the more external (material) aspect. Therefore, it can be inferred that individuals who are self-sufficient

and adopt a non-material life may be more sensitive in terms of having ethical concerns. As a result of the study within the specified framework, it was found that customer perceptions towards marketing ethics do not have an effect on the satisfaction and loyalty of customers who make planned shopping and prefer simple products in relation to the external (material) aspect of the voluntary simple lifestyle; It has been revealed that voluntary simplicity of life style has an effect on the satisfaction and loyalty of customers who prefer self-sufficient and non-material life in relation to its inner (spiritual) aspect.

RECOMMENDATIONS

RECOMMENDATIONS FOR THE LITERATURE

The study offers several recommendations for advancing the literature. First, future studies should integrate customer loyalty as a sub-dimension of relationship quality alongside customer satisfaction and trust to comprehensively assess its impact. This holistic approach can provide a more nuanced understanding of the dynamics between these variables.

Second, broadening the range of sub-business lines within the service sector and incorporating sectors from manufacturing can enhance the generalizability of research findings. By including a more diverse set of industries, researchers can better capture the variability in perceptions and behaviors across different sectors.

Third, integrating qualitative approaches, particularly when dealing with variables like marketing ethics and voluntary simplicity lifestyle, can ensure a comprehensive understanding of concepts and increase explanatory power in statistical analyses. Qualitative methods can provide valuable insights into the underlying motivations and perceptions of individuals, complementing quantitative findings. By adhering to these recommendations, future studies can enrich the literature and provide deeper insights into the complex dynamics between marketing ethics, customer satisfaction, trust, and loyalty, as well as the moderating effects of voluntary simplicity lifestyle.

RECOMMENDATIONS FOR THE SECTOR

In the sector, there are several key strategies that companies can implement to enhance their practices and relationships with customers. Firstly, company management should prioritize directive and developmental practices aimed at enhancing ethics in marketing activities. This can include incentive practices such as rewards and promotions, as well as providing training support to make employees more ethically sensitive.

Secondly, actively engaging in activities to enhance customer satisfaction and trust is essential for fostering long-term relationships with customers. Firms should invest in initiatives aimed at improving product quality, customer service, and communication channels to build trust and loyalty.

Third, acknowledging the significant impact of positive marketing ethics perceptions on customers with a voluntary simplicity lifestyle, companies should tailor their marketing strategies accordingly. Customers embracing simple lifestyles tend to exhibit higher levels of satisfaction and loyalty, emphasizing the importance of catering to their preferences in marketing approaches.

In addition to prioritizing simplicity in marketing practices due to the role of word-of-mouth marketing in customer satisfaction, companies should consider restricting budgets allocated for activities like advertising to ensure the satisfaction of customers embracing voluntary simplicity lifestyles. Moreover, accurately identifying the wants and needs of customers with high levels of self-sufficiency and offering alternative products can enhance loyalty among this

customer segment. Sales personnel should provide guidance to ensure customer satisfaction and offer alternative products at lower prices. Lastly, in regions with lower socio-economic development levels, companies should focus on improving relations and communications with customers, particularly among Generation Z with higher education levels. Taking corrective measures and reviewing marketing ethics activities can mitigate negative perceptions and enhance customer satisfaction, trust, and loyalty in these regions. By implementing these recommendations, companies can strengthen their relationships with customers, improve brand reputation, and ultimately enhance their competitiveness in the market.

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IS MEANING IN LIFE CHANGING IN CONTEMPORARY CROATIAN SOCIETY AND WHAT ARE THE POSSIBLE IMPLICATIONS OF THIS TREND FOR MEDICAL PRACTICE?

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ABSTRACT

Aim: This article explores the changes observed in meaning in life in contemporary Croatian society based on the data collected in a population survey of VAL-DE-END project. Methods: The survey was conducted in 2019 on a three-stage random sample, stratified by regions, counties, and locations within those counties (N = 1203) with a maximum sample error of ±2,8 %. The response rate was 30 %. By including weights, the sample became nationally representative in terms of sex, age, education, and regional representation. The instrument used consisted of 90 items. Results: 87,5 % of respondent think that family and friends give life meaning. More than 67% of respondents find it in contributing to the community. 64,1 % find meaning in life in self-realisation of one' own possibilities and 56,7 % in living as comfortably as possible. 47,1 % agree with the statement that death can have its meaning only when a person believes in God. Conclusion: If we compare our data to previously done surveys in Croatian population, we can observe process of secularisation and individuation taking place which can have implications for the medical practice.

KEY WORDS

meaning in life, death, healthcare, Croatia

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INTRODUCTION

When you start to work on a research project you start with a problem which you would like to solve with your fellow researchers. This is exactly how the project entitled "Values and decisions at the end of life" (VAL-DE-END IP -2016-06-2721), funded by Croatian Science Foundation, started. We wanted to address issues dealing with the end of life in the intensive care units in Croatia. We decided to do qualitative and quantitative research in paediatric and adult Intensice Care Units and among general population. Our research uncovered numerous issues regarding end-of-life decision making in the Intensive Care Units [1-4] but also shed a new light on issues that have been rarely explored in general population in Croatia [5-7].

This article will focus specifically on the research done in general population in Croatia and will try to summarise the main findings addressing mainly the following question: Is meaning in life changing in contemporary Croatian society?

A distinction should be drawn between the meaning "in" life and the meaning "of" life. Meaning "in" life is focused on an individual, a human person and on the meaningfulness that a person's life could exhibit [8]. Meaning in life reflects the feeling that one's existence has significance, purpose, and coherence [9]. Meaning "of" life in a narrow sense, deals with the answer to the question of what, if anything, makes life meaningful or not and is mainly addressed within philosophical thinking [10].

Research done on meaning in life affirms that meaning in life is a fundamental human need that influences both psychological and physical well-being and health. Moreover, meaning in life supports individual flourishing and promotes social flourishing. Meaning in life helps people cope with stress, uncertainty, anxiety, and trauma. All this has significant impact on health of an individual and social resilience [8, 9, 11]. It can also have significant influence on everyday medical practice and the way our patients make decisions about possible medical treatments and options at the beginning and the end of life.

METHODOLOGY

The sample and the instrument that was used in our population study have already been described in previous publications in detail [5-7]. The survey was conducted in 2019 on a three-stage random sample, stratified by regions, counties, and locations within those counties. The sample (N = 1203) of adult citizens of the Republic of Croatia was constructed in accordance with the 2011 census. The stated number of respondents at the overall level allows inference to the target population, with a maximum sample error of ± 2,8 %. The response rate was 30 %. By including weights, the sample became nationally representative in terms of sex, age, education, and regional representation.

The questionnaire used consisted of 90 items [5-7].

Data were processed in IBM SPSS Statistics 26. In addition to descriptive statistics, we used ANOVA. Factor analysis and the Chi-square were also used to test differences in respondents' answers in relation to the basic sociodemographic characteristics of the respondents. Multiple regression analysis and correlation analysis (bivariate correlation, Pearson's coefficient) were used to find predictors of and links with factors [5-7].

RESULTS

The sociodemographic data about the sample is presented in Table 1.

Majority of the respondents believe in God and consider themselves to be religious. However, only 35,4 % of respondents attended religious ceremonies at least once a month or more. Although majority of respondents do not classify themselves either right or left either conservative

or liberal on political spectrum most of them approve divorce but disapprove of abortion and homosexuality [5-7].

We have also explored respondents' experiences with death and dying and their attitudes regarding certain forms of end-of-life decision-making.

Table 1. Sociodemographic characteristics of the respondents.

Sample characteristics	*N*	Percentage
Gender		
Male	572	47,6
Female	631	52,4
Marital status		
Married	517	43
Not married	279	23,2
Divorced,	145	12,1
Widowed,	159	13,2
Extramarital union	77	6,4
Number of children		
Childless	389	32,2
One child	240	20
Two children,	343	28,5
Three children	134	11,2
Four children	70	5,9
Five to seven children	17	1.4
Education		
Unfinished primary school	79	6,6
Primary school (8 years)	257	21,4
Secondary vocational (1-3 years)	239	19,9
Secondary vocational (4 years and longer)	318	26,4
High school	103	8,6
2-3 years of higher education	69	5,7
College	110	9,1
Master's degree	23	1,9
PhD degree	4	0,3
Employment		
Employed	789	65,6
Unemployed	28	2.3
Retired	245	20,4
Type of settlement		
less than 2000 inhabitants	521	43,3
between 2-10 000 inhabitants	191	15,9
between 10-50 000 inhabitants	152	12,6
between 50-100 000 inhabitants	60	5
between 100-500 000 inhabitants	121	10,1
with more than 500 000 inhabitants	158	13,1
Income per household		
730 euro	424	35,3
730-1460 euro	372	30,9
1460-2920 euro	224	18,7
2920 euro and more	27	2,3

Majority of respondents experienced a death of a close person, father, or mother. Only small number experienced the death of their own child. Death of a pet was experienced by more than half of respondents. 42.2% of respondents cared for seriously ill person. 34,6 % of respondents cared for terminally ill person. When asked about the most important characteristics of a good death, most of the respondents mentioned the absence of pain and the presence and lack of burden on family and loved ones [5-7].

38,1 % of the respondents would grant a wish to dying persons who are experiencing extreme and unbearable suffering and withhold life-prolonging treatment and 37,8 % would respect wishes of such persons and withdraw life-prolonging treatment. 77 % of respondents think that withholding and withdrawing procedures should be regulated by law because of the fear of abuse. Opinions about the practice and regulation of euthanasia are divided. More open to euthanasia are those who are younger and middle-aged, with higher levels of education, living in big cities, and having more liberal worldviews. Assisted suicide is not considered to be an acceptable practice with only 18,6 % of respondents agreeing with it. 51,6 % would support the dying person's autonomous decisions regarding the end-of-life procedures [5-7].

MEANING IN LIFE

The items related to the meaning in life together with the respondents' answers are presented in Table 2.

Table 2. Respondents' answers to the items related to the meaning in life.

Item	I completely disagree	I disagree	I do not know, I am not sure	I agree	I completely agree	Ranking
Everything ends with death	18,6	28,5	21,0	18,1	13,8	31,9
Death is uncertain and unknown; it is pointless to even think about it.	8,3	19,3	17,2	32,4	22,8	55,2
Death can have its meaning only when a person believes in God.	13,8	15,6	23,2	29,4	17,8	47,1
When a man has lived his life, death is a natural calm.	4,0	5,9	21,0	39,8	29,3	69,1
Life has no meaning.	49,3	33,3	12,8	3,3	1,3	4,6
The meaning o in life is to contribute to the life of the community.	4,7	8,4	19,3	48,1	19,5	67,8
The meaning in life is in the self-realization of one's own possibilities.	2,8	11,1	22,0	44,7	19,4	64,1
The meaning in life is in fulfilling one's own desires, not in caring for others.	16,8	38,1	23,0	12,5	9,7	22,2
The meaning in life is to live it as comfortably as possible.	5,5	14,2	23,6	36,9	19,8	56,7
Outside of the individual and his needs, life has no meaning.	15,2	41,1	27,6	11,8	4,2	16,0
Only belief in God gives life meaning.	14,9	20,8	26,4	22,0	15,8	37,8
Family and friends give life meaning.	1,3	2,6	8,5	41,7	45,8	87,5
Only life in a community (society) has meaning.	4,2	7,1	22,1	38,7	27,9	66,6

The highest percentage of respondents 87,5 % think that family and friends give life meaning. 67,8 % of respondents finding mining in life in contributing to the community and 66,6 % think that only life in a community has meaning. 64,1 % find meaning in life in self-realisation of one' own possibilities and 56,7 % find meaning in life in living as comfortably as possible. 55,2 % think that there is no point in thinking about death since it is uncertain and unknown.

However, 47,1 % agree with the statement that death can have its meaning only when a person believes in God and 37,8 % with the statement that only belief in God gives life meaning.

PREDICTORS OF ATTITUDES TOWARDS MEANING IN LIFE

A factor analysis using component model, varimax rotation and GK dimensionality reduction criterion on 11 statements that thematically cover the meaning in life identified three factors. These three factors explain 55,07 % of variance. The first factor we called 'meaning in life in God' and comprises three items. The second factor we called 'the meaning in life in the individual' and comprises five items. The third factor we called 'meaning in life in family and community' and comprised four items. Results of factor analysis are shown in Table 3.

Table 3. Structure of varimax factors[1]. The extracted factors explain 55,07 % of the variance.

	THE MEANING IN LIFE AND DEATH IN GOD	THE MEANING IN LIFE IN THE INDIVIDUAL	THE MEANING IN LIFE IN FAMILY AND COMMUNITY
Only belief in God gives life meaning.	0,883		
Death can have its meaning only when a person believes in God.	0,839		
Everything ends with death	–0,568	0,530	
The meaning of life is in fulfilling one's own desires, not in caring for others.		0,682	
The meaning of life is to live it as comfortably as possible.		0,657	
Outside of the individual and his needs, life has no meaning.		0,578	
Death is uncertain and unknown; it is pointless to even think about it.		0,565	
Family and friends give life meaning.			0,708
Life has no meaning.			–0,642
When a man has lived his life, death is a natural calm.			0,607
The meaning of life is to contribute to the life of the community.			0,559

The obtained factors were first analysed with regard to the basic sociodemographic characteristics of the respondents. The analysis showed that elderly people, women, people with a lower level of education, those whose parents have a lower level of education and those from smaller settlements are more inclined to base the meaning in life in God. Also, elderly people, women, people with a lower level of education, those whose parents have a lower level of education and those from smaller settlements are more inclined to base the meaning in life in family and togetherness. Younger people, men, and those from larger cities tend to look for the meaning in life in living as comfortably as possible.

The obtained factors were then analysed with regard to the political orientation and religiosity of the respondents. Religious people and those politically oriented to the right are more inclined to seek the meaning in life in God. Religious people and those politically oriented to the right are more inclined to look for the meaning in life in family and togetherness. Non-religious

people and those politically oriented to the left are more inclined to look for the meaning in life in living as comfortably as possible.

Finally, the obtained factors were then analysed with regard to attitudes toward different end-of-life decision making practices and the experiences with death and dying. People with negative attitudes about euthanasia are more inclined to look for the meaning in life in God. People with positive attitudes about euthanasia are more inclined to look for the meaning in life in living as comfortably as possible. Respondents who experienced the death of a sibling, father, grandparent, formed or their own child more inclined to look for the meaning in life in God and in family and community.

DISCUSSION

If we compare our results to previously done research in Croatia (Table 4) we can find changes in meaning in life in Croatian population [5, 6, 12-14].

Table 4. Percentage of agreement of the respondents with different statements regarding life and death in general population and student population in different surveys.

	1997 (General popula-tion), %	2005 (Students), %	2017 (Students), %	2019 (General popula-tion), %
Everything ends with death	29,2	12,4	14,7	31,9
Death is uncertain and unknown; it is pointless to even think about it.	58,5	39,4	38,4	55,2
Death can have its meaning only when a person believes in God.	70,9	45,5	33,1	47,1
When a man has lived his life, death is a natural calm.	82,1	49,6	5,1	69,1
Life has no meaning.	7,4	5,5	9,8	4,6
The meaning in life is to contribute to the life of the community.	-	6,8	63,4	67,8
The meaning in life is in the self--realization of one's own possibilities.	-	6,8	77,8	64,1
The meaning in life is in fulfilling one's own desires, not in caring for others.	-	5,1	8,4	22,2
The meaning in life is to live it as comfortably as possible.	47,8	15,4	22,1	56,7
Outside of the individual and his needs, life has no meaning.	-	7,1	5,1	16,0
Only belief in God gives life meaning.	67,6	34,0	25,7	37,8
Family and friends give life meaning.	-	83,1	85,9	87,5
Only life in a community (society) has meaning.	-	54,0	51,2	66,6

There is a decrease with agreement with the statement that death can have its meaning only when a person believes in God. Furthermore, there is a decrease in agreement with the statement that only belief in God gives life meaning, both in general population and student population.

On the other hand, there is increase in general population and student population in agreement with the statement that everything ends with death. Moreover, lower percentage of general population and student population see death as a calm that comes naturally after life. Furthermore, there is an increase, both in general population and student population, in agreement

with the statement that the meaning of life is in the self-realization of one's own possibilities. Finally, high number of respondents agree with the statements that the meaning of life is in fulfilling one's own desires, not in caring for others and living life as comfortably as possible.

However, lower number of members of the general population but higher number of members of the student population think that life has no meaning. Interestingly, family, friends and community are still important source of meaning in life for general population and student population.

From these findings it is clear, that in the contemporary Croatian society orientation towards God as the basis of life and death decreases (as the result of secularization), while the understanding of the meaning in life through easy living increases (as result the orientation towards individualism) [15].

Our findings also have repercussions for medical practice. The concept of the meaning in life has certain values behind it that can be observed from our findings. These values can have implications for healthcare provision. That is why today we speak more and more about "value in health care" approach when it comes to healthcare provision. Value in health is measured as improvement in a person's health outcomes for the cost of achieving that improvement [16]. Cost reduction, quality of healthcare are somewhat related to this concept while patients' satisfaction only marginally. However, "value in health care" approach focuses primarily on the outcomes that matter most to patients [17]. Good healthcare provision takes place when patients are working in partnership with their healthcare professionals which enables patients to gain the shared understanding of medicine that allows the shared goal setting and decision making needed for truly person-centred care [18].

Since many of the respondents in Croatia still attribute importance to the community, solidarity as one of the key principles in healthcare provision in EU context, is something which should be considered as an important value when we talk about healthcare planning and delivery in Croatia [19]. This is even more important since Croatian healthcare system has already undergone several reforms in recent years in order to optimize the healthcare system in line with the current government's budget and achieve sustainability in the long run [20]. Through these reforms the healthcare system was often put under the constant threat of further commercialization and commodification (the incentive to transform healthcare from a granted right into a commodity) [21]. Therefore, there is no wonder that several studies among general population in Croatia show that lower income groups found it difficult to trust health care system and physicians and have negative views on physicians' priorities and their primary interests [7, 22] which in turn influences physician patient relationship.

The previous research done in Croatia shows various problems in physician patient relationship when it comes to reinforcement of patients' autonomy within physician patient relationship and trust among physician and patients [7, 22, 23]. However, personal wishes of the patients and their understanding through fostering of the partnership model of physician patient relationship are seen as essential in "value in health care" approach [23] and are gaining more and more importance in Croatian medical practice and probably will in the future [24].

Finally, secularization can have influence on the views on death and the meaning in life that in turn influence decision-making in medical practice at different stages in patient's life [25]. In the study regarding ethical dilemmas most frequently experienced by Croatian physicians and nurses in clinical practices, most commonly experienced dilemmas have to do with: the uncertain or impaired decision-making capacity of patients, imitation of treatment at the end of life and disagreements among family members [26]. Previous research in Croatia and our research regarding different end-of-life practices put Croatia among the countries with a low level of public acceptance of these practices [27-29]. Croatian respondents are less likely to

accept withholding and withdrawing life-prolonging treatments in comparison with other countries. Opinions about the practice and regulation of euthanasia are divided. Those who are younger and middle-aged, with higher levels of education, living in big cities, and who have a more liberal worldview are more open to euthanasia. Assisted suicide is not considered to be an acceptable practice. However, the support for the dying person's autonomous decisions regarding end-of-life procedures is quite high [6]. What will be the opinions of Croatian population regrading above mentioned end-of-life practices in the future remains to be seen.

REMARK

[1]Due to meeting the criteria of a simple structure in the first step, two items were omitted from the factor analysis: "The meaning of life is in the self-realization of one's own possibilities" and "Only life in a community (society) has meaning".

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EXAMINATION OF THE IMPACT OF TRUST IN INFLUENCERS AND PERCEIVED CONTENT QUALITY ON BRAND AWARENESS, CONSUMER INTERACTION, AND PURCHASE INTENT: THE CASE OF TÜRKIYE

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ABSTRACT

Nowadays, many brands are increasing their collaboration with Influencers. For this reason, many social media celebrities appear before social media users with new content every day. The ability of influencers to gain response is undoubtedly closely related to gaining the trust of users and the quality of the content they share. Otherwise, it will not be possible for Influencers to be effective through their followers. The aim of this study is to examine the impact of social media users' trust in Influencers and their quality perception of the content shared by these celebrities on brand awareness, consumer interaction and purchase intentions for the promoted products. Research data was obtained through an online survey form in January 2024. As part of the research, data was collected from a total of 350 participants across Türkiye. As a result of the research, it was determined that most participants purchased between 1-6 products because of influencer promotions. Although the participants largely follow Influencers in the fields of education, entertainment, food and beverage, technology and travel, one of the important research findings is that nearly half of the participants do not purchase any products. Again, because of the research, it was determined that most of the participants watched the promotional content of Influencers for a period of 1-3 hours. As a result of the research, it was determined that trust in Influencers and perception of content quality have a significant and strong effect on brand awareness, consumer interaction and purchase intention. It is evaluated that the research results will be useful for brands that consider collaborating with researchers and influencers working in this field.

KEY WORDS

trust in influencers, content quality, brand awareness, consumer interaction

CLASSIFICATION

JEL: M31, Q55

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INTRODUCTION

Presently, brands increasingly prefer collaborating with social media celebrities, mainly due to the vast user base of social media platforms and the influence influencers hold over their followers. Consequently, brands endeavor to increase consumer awareness, engagement, and ultimately influence product purchases by sharing content either independently or through influencer partnerships. Two types of content can be distinguished here: content shared by the brand itself and content shared by influencers with whom the brand collaborates. This study focuses on the content shared by influencers, which encompasses all content indicating an influencer's clear support for a luxury brand. Collaborating with influencers is commonly employed in social media content strategies by marketers because influencers exert varying degrees of influence over their numerous followers who emulate their behaviors and shape fashion trends [1, 2]. Influencer marketing has become one of the most popular and effective forms of online marketing. With millions of internet users browsing social media platforms for entertainment, inspiration, and product recommendations daily, it is no surprise that marketers are harnessing the power of social media's most recognizable faces for promotion. The global influencer marketing market value stood at 21,1 billion U.S. dollars as of 2023, having more than tripled since 2019. As influencer endorsement continues to mature as an industry, the size and value of influencer marketing platforms also continue to expand every year, making collaborations between brands and creators more profitable than ever [3]. During a global 2024 survey carried out among PR agencies, marketing agencies, brands, and other relevant professionals, 37,6 % of respondents stated that their organizations worked with up to 10 influencers, whereas 14,7 % said they worked with over a thousand influencers [4]. Influencer marketing activities are mostly carried out on social platforms such as Facebook, Instagram and Twitter [5]. Overall, 78 % of marketers find influencer marketing to be an effective strategy for increasing brand awareness. Instagram is the preferred platform for 87 % of influencers to collaborate with brands. Influencer campaigns outperform traditional advertising methods, resulting in an average engagement rate of 4,2 %. More than 60 % of consumers say they trust influencer recommendations when making purchasing decisions [6].

However, it is deemed necessary to further explore the characteristics of content created by influencers and the impact of trust in influencers in marketing campaigns conducted with influencers. Therefore, this study aims to contribute to the literature and provide insights to brands by examining the influence of social media users' trust in influencers and their perceived content quality on brand awareness, consumer engagement, and purchase intention concerning promoted products, with a focus on the Turkish context.

THE CONCEPT OF INFLUENCERS

The emergence of social media networks has provided opportunities for brands to utilize these platforms to achieve marketing and business objectives. Today, social media marketing is generally understood as an interdisciplinary and interfunctional process that often incorporates social media alongside other communication channels to deliver value to stakeholders and achieve corporate goals [7].

Social media influencers are defined as individuals who can communicate with social media users and promote products to target consumers. Influencers strive to develop close, long-term relationships with their followers while consistently producing valuable content on social media to inform and provide recommendations to their audience [8]. Influencers have emerged as a new type of marketing communication channel, functioning as content creators who receive monetary or non-monetary support in exchange for the content they create and share [9]. They are described as 'a new type of independent third-party validator shaping attitudes of their followers through the use of blogs, tweets, and other social media platforms' [10] and as

'individuals with a broad following network'. Today, influencers create content on a wide range of topics, including but not limited to fashion, childcare, construction, food, travel, hobbies, among others.

Prominent influencers in their field can contribute to the value and customer loyalty of the brands they collaborate with and help a company stand out against its competitors. They can positively impact the sales of the collaborating brand and even influence their stock market values [11]. Therefore, many brands today view collaboration with influencers as an indispensable part of their marketing efforts.

TRUST IN INFLUENCERS

Trust is the willingness of one party to be vulnerable based on the expectation that the other party will perform a specific action. It is also an act of vulnerability towards the actions of the trusted party without the ability to monitor or control them. A common consensus among various definitions of trust is that it involves the willingness of the trustor to be vulnerable to the actions of the trusted party based on the expectation that they will perform a specific action [12]. Trust in influencers undoubtedly influences followers' valuation of the content shared by influencers, their interest in the collaborating brand, and their perspective. According to researchers [13], trust is one of the most significant aspects of the relationship between influencers and their target audience, implying that influencers can only influence consumers when they trust them. Indeed, trust in influencers has been reported to have a positive effect on the credibility of the collaborating brand and subsequently leads to purchase intention [14]. An influencer perceived as more credible tends to have higher levels of competence and reliability, thus exerting a greater influence on the purchase behavior and intentions of the target audience. In this regard, content created by influencers may appear more trustworthy when based on shared values with consumers [15].

Researchers, [16], identified trustworthiness, social influence, argument quality, and information involvement as the most important factors influencing perceived information credibility by consumers. Their research results also indicate a strong and positive relationship between perceived information credibility and brand/video attitudes. Therefore, the reliability of provided product information and its endorsement by experts are of paramount importance.

In a study [17], it was found that messages created by influencers have informative value, and influencer reliability positively influences followers' trust in branded content created by influencers, which in turn positively affects brand awareness and purchase intention. Researchers [18], examined influencer posts and highlighted the importance of long-term relationships in gaining followers' trust, noting that trust in influencers develops over time. As a result, influencers, whom consumers see as reliable and sincere sources of information, bring together the sponsored content they produce online with their followers [19].

SOCIAL MEDIA CONTENT QUALITY

Approaching social media content quality from the perspectives of customers is crucial for organizations to establish and maintain positive online relationships with their social media customers. This is because when followers perceive that the content shared by influencers is not beneficial or does not contribute, they will stop following those influencers. Undoubtedly, this situation will also have a negative impact on the brands with which influencers collaborate.

Social media content quality can be defined as the perception of the accuracy, completeness, relevance, and timeliness of brand-related information on the social media pages of consumers, brands, or influencers [20]. Content quality encompasses comprehensiveness, accuracy, clear and actionable information. When it comes to content quality, headings such as competence,

accuracy, timeliness, and comprehensiveness stand out [21]. Additionally, it is known that innovative and engaging content increases consumer interaction and helps attract their attention to brands [22].

For example, the richness of content (images and videos) and the length of the message can increase the interaction and popularity of a post, while the originality and uniqueness of the content can influence influencer-follower relationships. The liveliness of shared content can contribute to the sharing of posts. Consequently, content quality can be considered an important factor influencing users' preferences and behaviors [23].

BRAND AWARENESS

Brand awareness is the fundamental and most crucial constraint in any search related to a brand and is a factor directly influencing consumers' purchasing decisions [24]. Brand awareness denotes consumers' ability to recognize and recall a brand in different situations. It comprises brand recall and brand recognition; the former represents customers' ability to recall a brand name, while the latter refers to customers' ability to identify a brand in the presence of a brand cue [25]. According to researcher [26], companies utilizing social media platforms can create awareness by promoting their brands and can convert this awareness into purchase behavior. Social media channels such as Instagram, Facebook, Twitter, and YouTube have increasingly become central in sharing and spreading information, leading brands to heavily invest in establishing a strong presence on these channels for awareness. Consequently, it is known that the quality of content brands publishes on social media influences individuals' brand awareness levels over time and facilitates their recognition and recall of the brand [27]. It is also known that brand awareness has an impact on consumer interaction on social media [28]. Within this context, the following hypotheses have been formulated:

H_1: Trust in influencers has a significant effect on brand awareness.

H_2: Perceived quality of social media content has a significant effect on brand awareness.

CONSUMER INTERACTION

Consumer interaction refers to the intensity of individual engagement initiated by consumers or businesses towards a brand's marketing activities [29]. Consumer interaction comprises cognitive, emotional, and behavioral dimensions. The cognitive and emotional dimensions of consumer involvement encompass customers' experiences, attitudes, intentions, and emotions towards a brand. Behavioral involvement, on the other hand, reflects a consumer's proactive efforts towards a brand. Researchers, [30] state that online consumer interaction is based on motivational factors such as initiating and sustaining word-of-mouth communication, providing recommendations, assisting other consumers, creating blogs, and writing comments. Additionally, consumer involvement is considered as behavioral responses developed by consumers towards a brand beyond purchasing. In behavioral involvement, consumers' voluntary contributions (such as sharing brand knowledge and experience with others, spending time, etc.) constitute extra-role behavior. Social media brand interaction, defined as a space for help, discussion, and idea exchange, has fundamentally transformed communication between brands and customers [31]. Consumer interaction has positive outcomes; for instance, it enhances perceived credibility [32]. Researchers [33], underscore the importance of regular updates and incentives on social media to generate interest in a brand. Moreover, it has been found that consumer interaction has a positive impact on business performance [34]. Regardless of its nature, content created by businesses supports user-generated content [35]. Within this context, the following hypotheses have been formulated:

H_3: Trust in influencers has a significant effect on consumer interaction.

H_4: Perceived quality of social media content has a significant effect on consumer interaction.

PURCHASE INTENTION

Purchase intention refers to the combination of consumers' interest in a brand or product and the likelihood of purchasing these products. It is strongly associated with attitudes and preferences towards a particular brand or product [36]. Consumer purchase intention is part of consumer cognitive behavior that reveals how a specific brand is expected to be purchased [37]. From social media brand communication, which creates its own celebrities like any other medium, to influencing consumer preferences, marketing is heavily focused on making its presence felt. Today, it is possible to encounter influencers on dozens of different topics ranging from personal care to decoration, from cars to agricultural tools and equipment. Influencers, who have millions of followers due to their popularity on social media, are known to influence consumer purchasing behavior. As the influence of traditional celebrities diminishes on consumer behavior, the influence of influencers increases [8]. It is known that high-quality content shared by influencers on social media can influence consumer beliefs and purchasing behavior [38]. Within this context, the following hypotheses have been formulated:

H_5: Trust in influencers has a significant effect on purchase intention.

H_6: Perceived quality of social media content has a significant effect on purchase intention.

RESEARCH METHODOLOGY

RESEARCH PURPOSE

In today's context, influencers, due to their millions of followers, play a fundamental role in brand communication efforts by brands. Influencers, which hold a highly significant position in brand communication, have been the subject of numerous studies. In this research, the impact of trust in influencers and the perceived quality of content created by influencers on consumer interaction, brand awareness, and purchase intention is examined.

SCOPE AND SAMPLE OF THE STUDY

This study was conducted in Turkey between January and February 2024. Convenience sampling, a non-probability sampling method, was employed to collect data. A link containing the survey form was shared on various social media platforms for data collection. The study reached 350 participants.

A 5-point Likert scale was used for the questions related to the scale in the prepared survey form. In the 5-point Likert scale, the evaluations were coded as follows: (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree.

DATA ANALYSIS

The first section of the survey included demographic questions. The second section contained statements related to trust in influencers, perceived quality of influencer-generated content, consumer interaction scale, brand awareness, and purchase intention scale. Data analysis in the study was conducted using the SPSS package program. Cronbach's Alpha coefficient was used to assess the reliability level of the scales in the study. Cronbach's Alpha coefficient is a statistical method that measures the internal consistency of a scale. Generally, values above

0,70 represent a good level of reliability, while values between 0,60 and 0,70 indicate acceptable reliability [39].

The scales used in the study, including content quality perception scale [20], consumer interaction scale [40], brand awareness scale [41] purchase intention scale [42], and trust in influencers scale [43], were obtained from previous studies. Before proceeding to factor analysis, a reliability analysis was conducted to evaluate the internal consistency of the scales, and Cronbach's Alpha value for all scales used was found to be 0,886 and above, indicating good reliability. A normality test was conducted to determine whether the data showed a normal distribution. The normality test examines the skewness and kurtosis values of the data groups. According to the literature, groups with skewness and kurtosis measures between +2 and –2 are considered to exhibit normal distribution [44]. The normality test conducted in this study revealed that all tests in the research showed normal distribution. Therefore, parametric tests were deemed appropriate for the analysis. To test the hypotheses of the study, Pearson correlation coefficient was calculated to examine the relationship between trust in influencers, perceived quality of influencer-generated content, consumer interaction, brand awareness, and purchase intention. Subsequently, simple linear regression analysis was applied to determine the impact of trust in influencers and perceived quality of influencer-generated content on consumer interaction, brand awareness, and purchase intention.

FINDINGS AND ANALYSIS

This section includes information on participants' demographic characteristics, the number and domain of influencers they follow, and their product purchasing behavior due to influencer influence. Additionally, this section presents the results of factor analyses, validity and reliability analyses of the scales, and regression analysis testing the hypotheses.

Table 1. Demographic characteristics of participants.

Education	**F**	**%**	**Income**	**F**	**%**
Primary School	7	2,0	12,000 TL and below	112	32,0
High School	112	32,0	12001- 18000	52	14,9
University	193	55,1	18001-24000	48	13,7
Master's/Ph.D.	38	10,9	24001-30000	49	14,0
Occupation	**F**	**%**	30001-36000	41	11,7
Private Sector Employee	106	30,2	36001-40000	17	4,9
Public Sector Employee	94	26,8	40,0001 TL and above	31	8,9
Student	75	21,4	**Age**	**F**	**%**
Self-Employed	34	9,7	18-24	108	30,8
Homemaker	21	6,0	25-31	80	22,8
Retired	15	4,2	32-38	56	16,0
Unemployed	6	1,7	39-45	50	14,2
Gender	**F**	**%**	46 and above	56	16,0
Female	187	53,4			
Male	163	46,5			

Table 1 provides information on the demographic characteristics of the participants. Upon reviewing the table, it can be observed that many of the participants are university graduates, have a monthly income of 12 000 TL or less, are mostly employed in the private sector, fall within the age range of 18-24, and females are predominant in the study. Table 2 contains information about the participants' attitudes and behaviors towards Influencers.

Table 2. Participants' attitudes and behaviors towards influencers.

Product Purchase Status Following Influencer Promotion	**F**	**%**	**Followed Influencer Field**	**F**	**%**

Purchased 1-3 products	137	39,1	Education	196	56
Purchased 4-6 products	41	11,7	Entertainment	165	47,2
Purchased 7 or more products	27	7,7	Food & Beverage	159	45,4
Did not purchase any products	145	41,4	Technology	154	44
Duration of Watching Influencer Promotions	**F**	**%**	Travel	146	41,7
Less than 1 hour	172	49,1	Fashion	139	39,7
1-3 hours	125	35,7	Personal Care	137	39,1
4-6 hours	48	13,7	Cosmetics	111	31,7
7 hours or more	5	1,4	Automotive	88	25,1
Number of Influencers You Follow	**F**	**%**	Hunting	22	6,3
Follow 1-3 influencers	187	53,4	Other	5	1,5
Follow 4-6 influencers	74	21,1	I do not follow	1	0,3
Follow 7-10 influencers	37	10,6			
Follow 11 or more influencers	52	14,9			

Table 2 presents participants' attitudes and behaviors towards Influencers' promotional activities. Upon examining the table, it is evident that the majority of participants have purchased 1-6 products as a result of Influencer endorsements. Although participants predominantly follow Influencers in the fields of education, entertainment, food and beverage, technology, and travel, it is apparent that nearly half of the participants have not made any purchases. Furthermore, upon reviewing the table, it is noted that the majority of participants watch Influencers' promotional content for a duration of 1-3 hours. Table 3 presents information about the factor analysis results of consumers' purchase intention, brand awareness and consumer interaction scales.

Table 3. Factor analysis results of purchase intention, brand awareness, and consumer interaction scales.

	Factors		
	1	2	3
PI3	0,842		
PI4	0,773		
PI2	0,770		
PI1	0,719		
BA3		0,773	
BA		0,772	
BA1		0,746	
BA2		0,728	
CI2			0,848
CI1			0,783
CI3			0,594
Explained Variance	**31,061**	**30,74**	**24,074**
Total Explained Variance			**85,290**
KMO (Kaiser-Meyer-Olkin) Sample Adequacy			**0,944**
Bartlett's Sphericity Test Chi-Square value			**4207,594**
Sd (Degrees of Freedom)			**55**
p value			**0,001**

Table 3 presents the results of the factor analysis of the Purchase Intention, Brand Awareness, and Consumer Interaction scales. According to the table, it has been determined that the

eigenvalues of the three factors are greater than 1. The criterion of eigenvalues greater than 1, as determined through factor analysis, is a commonly used criterion for determining the number of factors to be included in the scale [45]. This criterion emphasizes that eigenvalues are associated with the structural integrity of the scale and the compatibility of the factors. During the factor analysis process, the Kaiser-Meyer-Olkin (KMO) value was first calculated, and Bartlett's Sphericity test was examined. According to the KMO test, if the calculated value is less than 0,50, it indicates that continuing with the factor analysis is not appropriate [46]. This finding is considered an important criterion for evaluating the structural integrity and relationship between factors. In the present study, the KMO value is found to be greater than 0,50. The total explained variance is 85,290 %. According to the results of the factor analysis, it is observed that the factor loading values of the items underlying the factors range from 0,594 to 0,848. Table 4 contains information about the factor analysis results of the participants' trust in influencers and content quality perception scales.

Table 4. Factor Analysis Results of Trust in Influencers and Content Quality Perception Scales.

	Factors	
	1	2
TI6	0,859	
TI5	0,853	
TI4	0,839	
TI3	0,834	
TI1	0,822	
TI2	0,805	
CQP1		0,873
CQP3		0,826
CQP2		0,741
Explained Variance	**51,995**	**32,037**
Total Explained Variance		**84,032**
KMO Sample Adequacy		**0,940**
Bartlett's Sphericity Test Chi-Square value		**3447,096**
Sd (Degrees of Freedom)		**36**
p value		**0,001**

According to the data in Table 4, it was determined that the eigenvalues of the two factors are greater than 1. In the conducted study, the KMO value is found to be greater than 0,50. The total explained variance is 84,032 %.

Table 5. Information about the Scales.

Factor name	Cronbach alfa	Number of variants	Mean
Factor 1. Trust in Influencers	0,964	6	2,43
Factor 2. Content Quality Perception	0,888	3	2,40
Factor 3. Brand Awareness	0,945	4	2,54
Factor 4. Consumer Interaction	0,886	3	2,47
Factor 5. Purchase intentions	0,945	4	2,42

Table 5 presents the results of the reliability analysis of the scales used in the study. According to these results, all scales used in the research have Cronbach's Alpha values above 0,70, indicating high reliability.

HYPOTHESIS TESTING

At this stage of the research, the direction and strength of the relationships were analyzed using correlation analysis. Correlation analysis provides information about the direction and strength

of the relationship between two different variables. In correlation analysis, values in the range 0,00-0,30 indicate a low-level relationship, values in the range 0,30-0,70 indicate a medium-level relationship, and values in the range 0,70-1,00 indicate a high-level relationship [45]. The amount of relationship between the variables used in the research and the direction of the relationship were examined through correlation analysis, and the correlation coefficients between each variable were calculated, with the analysis results presented in Table 6.

Table 6. Correlation analysis results between the variables used in the research.

		Consumer Interaction	**Content Quality Perception**	**Brand Awareness**	**Purchase intentions**	**Trust in Influencers**
Consumer Interaction	Pearson Correlation	1				
Content Quality Perception	Pearson Correlation	0,828**	1			
Brand Awareness	Pearson Correlation	0,810**	0,843**	1		
Purchase intentions.	Pearson Correlation	0,782**	0,813**	0,832**	1	
Trust in Influencers	Pearson Correlation	0,697**	0,766**	0,731**	0,772**	1

**significant at the 0,01 level (2-tailed)

According to the correlation analysis conducted in the research, all the correlation coefficients between variables were found to be significant ($p < 0,01$). Consequently, it can be stated that there is a strong positive relationship between consumers' trust in influencers and their perceptions of content quality with consumer interaction, brand awareness, and purchase intentions.

At this stage of the research, the test results of the formulated hypotheses are presented. Due to the hypotheses consisting of one independent and one dependent variable, simple linear regression analysis was employed for hypothesis testing.

Table 7 shows the simple linear regression analysis results on the effect of trust in influencers on brand awareness. Upon examining the analysis' results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, trust in influencers, and the dependent variable, brand awareness, at a level that could be considered strong ($R = 0,731$, $t = 19,959$ and $p = 0,001$). When reviewing the table, it can be stated that 75 % of the total variance in brand awareness is explained by participants' levels of trust in influencers. Therefore, $\mathbf{H_1}$, stating that trust in social media influencers positively affects brand awareness, is accepted.

Table 7. Results of simple linear regression analysis on the effect of trust in influencers on brand awareness.

Independent	**Dependent**	**B**	**Std. Error**	***β***	***t***	***p***
Trust in Influencers	Constant	0,662	0,104		6,364	0,001
	Brand Awareness	0,770	0,039	0,731	19,959	0,001
$R =$ 0,731	$R^2 =$ 0,7534	$F =$ 398,348			$p =$ 0,001	

Table 8 shows the simple linear regression analysis results on the effect of content quality perception on brand awareness. Upon examining the analysis results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, content quality perception, and the dependent variable, brand awareness, at a level that could be considered strong (R = 0,843, t = 29,223 and p = 0,001). When reviewing the table, it can be stated that 71 % of the total variance in brand awareness is explained by participants' levels of content quality perception. Therefore, **H_2**, stating that social media content quality perception positively affects brand awareness, is accepted.

Table 8. Results of simple linear regression analysis on the effect of content quality perception on brand awareness.

Independent	Dependent	*B*	Std. Error	*β*	*t*	*p*
Content Quality Perception	Constant	0,354	0,083		4,285	0,001
	Brand Awareness	0,911	0,031	0,843	29,223	0,001
R = 0,843	R^2 = 0,710	F = 853,966			p = 0,001	

Table 9 shows the simple linear regression analysis results on the effect of trust in influencers on consumer interaction. Upon examination of the analysis results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, trust in influencers, and the dependent variable, consumer interaction, at a level that could be considered strong (R = 0,697, t = 18,140 and p = 0,001). When reviewing the table, it can be stated that 48,6 % of the total variance in consumer interaction is explained by participants' levels of trust in influencers. Therefore, **H_3**, stating that trust in social media influencers positively affects consumer interaction, is accepted.

Table 9. Results of simple linear regression analysis on the effect of trust in influencers on consumer interaction.

Independent	Dependent	*B*	Std. Error	*β*	*t*	*p*
Trust in Influencers	Constant	0,768	0,104		7,410	0,001
	Consumer Interaction	0,698	0,038	0,697	18,140	0,001
R = 0,697	R^2 = 0,486	F = 329,061			p = 0,001	

Table 10 shows the simple linear regression analysis results on the effect of content quality perception on consumer interaction. Upon examination of the analysis results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, content quality perception, and the dependent variable, consumer interaction, at a level that could be considered strong (R = 0,828, t = 27,556 and p = 0,001). When reviewing the table, it can be stated that 68.6% of the total variance in consumer interaction is explained by participants' levels of content quality perception. Therefore, **H_4**, stating that content quality perception on social media positively affects consumer interaction, is accepted.

Table 10. Results of simple linear regression analysis on the effect of content quality perception on consumer interaction.

Independent	Dependent	*B*	Std. Error	*β*	*t*	*p*
Content Quality Perception	Constant	0,082	0,104		5,271	0,001
	Consumer Interaction	0,031	0,038	0,828	27,556	0,001
R = 0,828	R^2 = 0,686	F = 759,335			p = 0,001	

Table 11 shows the simple linear regression analysis results on the effect of trust in influencers on consumer purchasing intention. Upon examining the analysis results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, trust in influencers, and the dependent variable, consumer purchase intention, at a level that could be considered strong (R = 0,772, t = 22,622 and p = 0,001). Upon reviewing the table, it can be stated that 60 % of the total variance in consumer purchase intention is explained by participants' levels of trust in influencers. Therefore, **H5**, stating that trust in influencers positively affects purchase intention, is accepted.

Table 11. Results of simple linear regression analysis on the effect of trust in influencers on consumer purchase intention.

Independent	Dependent	*B*	Std. Error	*β*	*t*	*p*
Trust in Influencers	Constant	0,497	0,094		5,283	0,001
	Consumer Purchase Intention	0,790	0,035	0,772	22,622	0,001
R = 0,772	R^2 = 0,595	F = 511,761			p = 0,001	

Table 12 shows the simple linear regression analysis results on the effect of content quality perception on consumer purchasing intention. Upon examining the analysis results, it is evident that there is a statistically significant, positive linear relationship between the independent variable, Content Quality Perception, and the dependent variable, consumer purchase intention, at a level that could be considered strong (R = 0,813, t = 26,049 and p = 0,001). Upon reviewing the table, it can be stated that 66 % of the total variance in consumer purchase intention is explained by participants' levels of Content Quality Perception. Therefore, **H6**, stating that social media content quality perception positively affects purchase intention, is accepted.

Table 12. Results of simple linear regression analysis on the effect of content quality perception on consumer purchase intention.

Independent	Dependent	*B*	Std. Error	*β*	*t*	*p*
Content Quality Perception	Constant	0,376	0,087		4,328	0,001
	Consumer Purchase Intention	0,854	0,033	0,813	26,049	0,001
R = 0,813	R^2 = 0,661	F = 678,552			p = 0,001	

Table 13 presents the Acceptance/Rejection status of the research hypotheses. Upon examination of the table, it is observed that all six hypotheses are accepted.

Table 13. Acceptance/Rejection status of research hypotheses.

Hypothesis	Accepted/ Rejected
H1: Trust in influencers has a significant effect on brand awareness.	Accepted
H2: Perceived quality of social media content has a significant effect on brand awareness.	Accepted
H3: Trust in influencers has a significant effect on consumer interaction.	Accepted
H4: Perceived quality of social media content has a significant effect on consumer interaction	Accepted
H5: Trust in influencers has a significant effect on purchase intention.	Accepted
H6: Perceived quality of social media content has a significant effect on purchase intention.	Accepted

RESULTS AND DISCUSSION

In recent years, research conducted on Influencers, with whom brands have been collaborating extensively, revealed that most participants made purchases ranging from 1 to 6 products as a result of influencer promotions. Although participants predominantly follow Influencers in the fields of education, entertainment, food and beverage, technology, and travel, it is also noteworthy that nearly half of them did not make any purchases. Furthermore, the research indicated that most participants watched influencer promotional content for a duration of 1-3 hours.

Additionally, the study aimed to examine the impact of consumers' trust in Influencers and their perceptions of content quality created by Influencers on brand awareness, consumer engagement, and purchase intention. All hypotheses formulated in this regard were accepted. The research findings demonstrated a significant positive relationship between consumers' trust in Influencers and their brand awareness, consumer engagement, and purchase intention. Researchers, [47] similarly found in their research that influencer credibility significantly influences attitudes toward products and services. Researchers [48], also found in their research that trust in Influencers has a positive effect on consumers' purchasing behavior. Likewise, according to researchers [49], an influencer perceived as trustworthy may have a greater impact on target groups' purchasing behavior and intentions due to their higher perceived competence and reliability. Researchers [50], indicated in their research that the credibility of Influencers positively influences consumers' purchase intentions, with brand trust having a positive effect. However, researchers, [51] found in their research that the hypothesis stating that trust in Influencers has a direct positive impact on followers' purchase decisions was rejected, suggesting a potential difference within the sample context.

Furthermore, the research revealed that consumers' perception of content quality created by Influencers has a strong positive effect on their brand awareness, consumer engagement, and purchase intention. These findings align with those of researchers [52], who emphasized the significance of content in consumer engagement. Researchers [20], found in their research that the perception of content quality positively affects brand awareness. Dabbous and Barakat [53] demonstrated in their research that the perception of content quality has a positive indirect effect on brand awareness and a direct positive effect on consumer engagement and purchase intention. Researchers [53], found in their study that content shared by Influencers containing understandable, reliable, innovative, interesting, and high-quality information has a strong positive impact on consumer engagement.

In conclusion, consumers follow social media Influencers with the expectation of providing them with useful information. It should be noted that having many followers does not necessarily mean unconditional trust from followers. Therefore, it should be recognized that the path for an influencer to sustain this profession in the long term lies in gaining the trust of their followers. Undoubtedly, the alignment between an influencer and their followers will increase the trust of followers and contribute to an increase in their willingness to purchase advertised products. Therefore, before collaborating with Influencers, brands should conduct research on their credibility among their followers and the quality of the content they share, which will significantly enhance the outcomes of the collaboration.

Finally, in terms of limitations of the study, the relatively small sample size and the use of convenience sampling method for determining the sample are the most significant constraints.

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CONTRIBUTION OF NEW STANDARD ISO 9001:2015 TO THE QUALITY

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Brief report

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ABSTRACT

ISO 9001:2015 is an international standard which defines the minimum requirements for the quality management system. It is part of an overall family of Standards known as ISO 9000ff. ISO 9001 standard is applicable to any type of business and companies of all sizes and can help organisations to provide consistent products and services leading to customer satisfaction, regulatory compliance and continual improvement. It is the most popular, best-selling and best-known standard in the world and the only standard in the ISO 9000 family to which organizations can certify. Since the first edition in 1987, there have been several revisions of ISO 9001 standard, and the last revision was made in 2015. The valid version of ISO 9001 standard was released in September 2015 and changes made in requirements of ISO 9001:2015 are much more significant than those made in the 2008 revision. The main changes are in structure of ISO 9001:2015, where the number of chapters increased from 8 to 10 and in completely new requirements which include context of organization, risk management, knowledge as resource and leadership. There were great expectations from these changes, and the paper explain whether these changes achieved the expected results on quality.

KEY WORDS

quality, ISO 9001:2015, quality management system, risk

CLASSIFICATION

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INTRODUCTION

Global market changes, new production technologies, new requirements of global manufacturing companies and suppliers, increasing customer requirements and other interested parties, limitations of target markets, condition such management of business systems, in which management must find efficient and quick solutions. Only quality management systems that continuously improve operations lead to a better position on the global market and increase of customer satisfaction.

The goal of every organization is very clear: to live and succeed. This means producing what the market wants, with a certain level of quality, an acceptable price and delivery times, continuously increasing the satisfaction of customers and other interested parties. Quality, according to many in the world, is considered the most significant phenomenon of our time with a permanent trend of increasing importance. The question is how to achieve this and is it ISO 9001 standard the solution?

The history of the ISO 9001 quality management system begins in the 1950s when the US and UK governments introduced standards for military procurement. Large organizations supplying services and products to government agencies often had to adhere to certain quality assurance requirements for each contract awarded, which caused the defence industry to adopt mutual respect for NATO AQAP, MIL-Q and Def Stan standards.

The first edition of the ISO 9001 standard was published in 1984. by the International Organization for Standardization (ISO), an independent nongovernment body that develops standards to ensure the quality and safety of products and systems. This was followed by revisions from 1994, 2000 and 2008. The valid version of ISO 9001 standard was released in September 2015 and changes in requirements made in ISO 9001:2015 are much more significant than those made in the 2008 revision [1]. The main changes in ISO 9001:2015 include the completely new requirement ‘context’ of the organization, risk management, there is no longer a requirement for preventive actions, the concept of interested parties is introduced, and increased leadership requirements.

KEY CHANGES IN REQUIREMENTS OF ISO 9001:2015 COMPARED TO ISO 9001:2008

Valid revision of the ISO 9001 standard, published in September 2015. brings more significant changes compared to the previous revision from 2008, namely: organizational context, risk-based thinking, knowledge as a resource and leadership.

The number of chapters in valid revision from 2015. has been increased from 8 to 10 chapters [1], and this chapters are harmonized with “Annex SL”, which sets a template for chapters of all other standards which can be integrated into the one integrated management system like ISO 9001, ISO 14001, ISO 45001, ...

Table 1. Comparison of standard ISO 9001:2008 and ISO 9001:2015 chapters.

Chapter Number	ISO 9001:2008	ISO 9001:2015
1	Scope	Scope
2	Normative Reference	Normative References
3	Terms and Definitions	Terms and Definitions
4	General Requirements	Context of the Organization
5	Management Responsibility	Leadership
6	Resources	Planning
7	Production	Support
8	Measurement, Analysis and Improvement	Operation
9	-	Performance Evaluation
10	-	Improvement

The "context" of the organization (it can also be mentioned as business environment) refers to the combination of internal and external issues that can be effect on organization's approach to its production and services. As a result, implementation of an organization's QMS will be influenced by its context. This is a completely new requirement and did not exist in ISO 9001:2008 and it is very problematic for the auditors to check conformity of this requirement during the audit [2].

The organization must identify those external and internal issues (positive and negative) that are relevant to its "context" and that can affect the ability to achieve the desired outcome of the quality management system. In the ISO 9001:2015 standard, there is no obligatory requirement that these internal and external issues have to be documented by the organization, which makes it difficult for auditors to check the implementation of this requirement during the audit; organizations should consider these, but they do not have to document it and analyse the effectiveness of the organization's response to this issues.

However, in many cases this information can be check during audit from several sources. It can be part of the organization's business plan or business strategy, for example, or it can be stated on the organization's website, in its annual reports, or it can be one part of the Management's assessment. However, there is a possibility that such documented information is not available because the standard does not require for it as such, so auditors in that situation need to interview senior management in relation to the organization's context. Since the organization has to consider its 'strategic direction' when identifying internal and external issues, it is likely that discussion of these elements of an organization's context will have to involve senior management.

Depending on the organizational chart of the organization, its Quality Manager (which is not an obligatory requirement in the new version of ISO 9001:2015), for example, may not have sufficient knowledge of the context of the organization and may not be able to provide the information necessary for auditors to check compliance with the requirements of this point of the standard. From the past experience of the author of this paper as auditor, in the majority of cases, organizations have kept the quality manual, which is no longer a mandatory document regarding to ISO 9001:2015 standard, harmonized it with the points of the new standard ISO 9001:2015 and described their "context" of the organization and interested parties under point 4.

In particular, this problem applies to production organizations because their Quality Manager or even the top management sometimes do not have to know the issues of the production process itself, so it is accordingly much more difficult to determine the context of the organization resulting from the product that is delivered to customers. Accordingly, how can organizations prove that they consider external and internal issues when they do not have to conduct analysis or documented information about this consideration. Therefore, the authors of this paper consider that, for the stated reason, this requirement should be better defined in some new version of ISO 9001 standard.

Another new requirement in ISO 9001:2015 standard is incorporation of "Risk management" concept in requirements for the implementation, maintenance and continual improvement of the quality management system.

In ISO 9000:2015, "Quality management systems - Fundamentals and vocabulary", risk is defined as the "effect of uncertainty". The note in the definition also describe risk as a "deviation from the expected", whether positive or negative. The term "uncertainty" is explained as the lack of information about a possible event that can be expressed in terms of consequences and the probability that the event will occur. Likewise, ISO 9000:2015 states that risk is associated with a potential event and is usually expressed as a weighting of the probability and consequences of such an event [2].

Considering the description of the requirements of the standard related to risks and opportunities and the absence of any direct requirements for documenting risks, except for the assessment of actions related to risks and opportunities as an input requirement of the management assessment, as well as the obligation to use some of the recognized methods for risk assessment such as is, for example, the Failure Mode and Effect Analysis (FMEA) method, it would be desirable for some new revisions of the standard to consider a more detailed definition of risk requirements, especially since organizations have a varied approach to implementation regarding this requirement. From the experience of the authors of this paper, organizations mostly assess risks using a recognized method for risk assessment and keep documented information about this assessment in a way that they make an FMEA analysis for all steps in the flow diagram of the process and for defined risks in the same document they also define action plans for identified risks.

The IATF 16949:2016 standard (Automotive QMS Standard issued by International Automotive Task Force) defines the risk requirements much better than ISO 9001:2015. Therefore, it is recommended that IATF 16949:2016, which is a requirement for production organizations in the automotive industry, be considered as a guideline for expanding and clarifying the application of ISO 9001:2015 in a wide range of organizations, especially in the area of risk assessment.

CONCLUSION

Standards of the ISO 9000ff series have played a very important role in the perception of quality and quality management in the last forty years. Although originally European, the ISO 9001 standard is now accepted worldwide and ISO 9001 is becoming a worldwide movement. This generally accepted standard should satisfy the needs and requirements of companies of various activities, which is not always easy due to the specific nature of the activity.

ISO 9001:2015 increased the number of chapters from 8 to 10 and definitely much more better define the specific requirements of standard which ISO 9001:2008 left unclear [1], but it would be desirable that in some new revisions of the standard, a more detailed definition of risk requirements should be considered, especially because organizations have a varied approach to this requirement in implementation due to the absence of any direct requirements for documenting risks, as well as the obligation to use one of the recognized methods. for risk assessment.

Likewise, it would be desirable to define a time period for the conduction of internal audits and Management review, which was missed in the ISO 9001:2015 edition [3].

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Interdisciplinary Description of Complex Systems 22(5), 616-632, 2024

DETERMINING THE MOST SUITABLE BUS MODEL FOR THE URBAN TRANSPORTATION SECTOR: A HYBRID MULTI-CRITERIA DECISION-MAKING APPROACH

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ABSTRACT

One of the key service elements of travel companies operating in the road transportation sector are passenger buses. Deciding to purchase a new bus requires managers to consider various aspects, complicating the decision-making process. In this context, implementing Multi-Criteria Decision Making (MCDM) methodologies in such decision problems can provide more accurate and effective solutions. The aim of this study is to investigate the new bus purchase decision processes of travel companies operating in Turkey with MCDM methods and to determine the most suitable bus model. Ten major bus models were analyzed in the study using four different MCDM approaches based on four major criteria and 16 sub-criteria. The weights of the criteria used in the evaluation of the relevant decision problem were determined by the Entropy method. Moreover, WASPAS, EDAS, and Gray Relational Analysis were utilized separately to discover the best suitable alternative. Furthermore, the rankings generated by these several MCDM approaches were compared using Spearman Rank Correlation Analysis in the study, and they were found to be highly consistent. The study provides several key recommendations for academic research and industry practice moving forward.

KEY WORDS

intercity passenger transport, entropy method, EDAS method, WASPAS method, grey relational analysis method

CLASSIFICATION

JEL: C44, C51, C61, R42

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INTRODUCTION

Transportation may be characterized as the movement of people and goods from one location to another. Today, investments in transportation infrastructure and the implementation of multilateral transportation policies have led to the development of transportation systems. Thus, transportation has evolved into a service sector that is important in terms of economic, social, and geographical interaction. Developments in transportation systems have played a significant impact on the development of the travel and tourism industry. Changing needs and increasing travel demands have made it necessary for businesses operating in this sector to renew their services [1]. In recent years, more importance is attached to concepts such as technology, comfort, and speed, as well as economy and safety.

In Turkey, road transport is one of the most popular types of passenger transportation. With the additional value, employment, and new services it provides, road passenger transportation has become a highly demanded service industry over the years. However, as road passenger transportation has grown in popularity and the number of operators has grown, the industry has become more competitive [2]. In terms of the continuity of travel businesses, it has become crucial to lower transportation costs and implement regulations that are compatible with changing technology and client expectations [3]. Therefore, in this sector, the necessity of taking the most effective decisions with the least administrative and strategic mistakes has emerged. In the decision-making processes of travel firms, scientific decision-making procedures based on reliable and exact data are critical.

It is strategically important for businesses to make evaluations with scientific decision-making methods in order to survive in the competitive environment and to continue their activities, apart from intuitive judgements, in their decision-making processes [4]. Especially in recent years, MCDM methods, which have become important and widely used in the literature of operations research, provide significant benefits to managers in evaluating multiple criteria together and reaching the best solutions. However, it has been determined that the relevant travel companies do not use MCDM methods in such decision problems [5].

In the contemporary travel industry, determining the most suitable bus model is crucial due to its significant impact on operational efficiency, customer satisfaction, and environmental sustainability. With increasing competition in the intercity bus sector, companies must choose bus models that align with evolving customer expectations, including comfort, technology, and fuel efficiency. Moreover, as environmental regulations become stricter, selecting buses that minimize emissions and optimize fuel consumption is essential for compliance and reducing operational costs. Additionally, the choice of bus model influences the overall service quality and operational performance of transit companies, which can directly affect their market position and profitability. Therefore, a strategic and well-informed approach to bus model selection is vital for travel companies aiming to enhance their service offerings and sustain competitive advantage in a rapidly changing industry landscape.

This study covers Entropy, EDAS, WASPAS and Gray Relational analysis methods separately and analyzing the alternatives in the selection of the most suitable bus model for intercity travel companies.

Selecting the most appropriate bus model is a process that should be approached with all of its aspects, including the quality of the services provided and the costs that may occur. For this purpose, first of all, criteria that can be effective in the decision problem discussed in the study were determined. For this, the criteria used in the studies on vehicle selection in the literature and the opinions of the expert team working as a manager in travel businesses operating in Turkey were used.

Since selecting the best appropriate bus model for intercity transportation is an evident decision issue, the study's theoretical background includes a basic fact of decision theory. In order to support the theoretical background, first of all, a comprehensive literature study was conducted. As a result of the literature review, no study using MCDM approaches to find the best bus model for intercity transit was detected. In addition, all MCDM methods that will provide the optimum solution of the relevant decision problem have been examined. Among these, both current and classical methods were used separately in the study. The results were compared in terms of the reliability of the findings.

In terms of the original value of the study, the analysis stages of the MCDM methods used to strengthen the reliability of the findings during the application phase were not carried out using manual or package programs. The analysis steps of each decision-making method were performed in the MATLAB program and the alternatives were evaluated according to their priorities. In this regard, a different solution procedure has been used than in previous studies on MCDM methods.

This study aims to address the gap by applying various prominent MCDM approaches to determine the most suitable bus model for the travel industry. The research focuses on the application of MCDM methods to tackle the complexities involved in bus model selection, treating this problem as a complex decision-making scenario within the travel sector. By examining the bus selection process through the lens of complex systems, the study highlights how these methods can systematically evaluate and prioritize different criteria. While the study does not integrate artificial intelligence optimization techniques such as ant-colony optimization or genetic algorithms, it emphasizes the effectiveness of MCDM methods in providing a structured and comprehensive framework for making informed decisions. This approach aims to align with the evolving demands of the travel industry, offering enhanced strategic outcomes through a robust and detailed analysis.

In the conclusion and evaluation part of the study, the study was compared with the studies on the closest subject, and academic and sectoral suggestions were given to shed light on similar studies to be done in the future. The study is expected to make a significant contribution to the literature on travel business decision problems.

LITERATURE REVIEW

RELATED STUDIES ON THE ROAD TRANSPORT SECTOR

The operations of road passenger transport services have changed through time as the road transportation network has developed. The need to review and improve the operations in this service sector has emerged as service capacity has grown and competition has increased. Research on assessing service quality, customer satisfaction, selecting the most appropriate transportation vehicles, and evaluating company performance are prevalent in studies on road passenger transportation. AHP and TOPSIS multi-criteria decision-making methods are used more frequently in these studies.

The bus vehicles operated by the companies are one of the most essential elements of road passenger transport activity. In terms of travel firms, when purchasing new vehicles that are economical, safe and comfortable, managers in the decision-making position have to evaluate from many criteria, which complicates the decision-making process. Studies on vehicle selection with MCDM methods in domestic and foreign literature have been examined and no specific study has been found in the literature on the selection of bus models for intercity passenger transportation, which is the subject of the research. some studies on road passenger transportation and vehicle.

[6] used the TOPSIS technique to examine the performance of road bus firms based on production, marketing, and execution factors, considering transportation and financial data. According to the findings of the study, utilizing financial data to measure the performance of bus firms can yield more effective outcomes.

[7] used Fuzzy TOPSIS and Fuzzy Preference Selection Index (PIS) approaches to select the best choice among bus models with various fuel kinds. As a result of the analysis made with the two new MCDM methods proposed in the study, the best alternatives were diesel engine, CNG (compressed natural gas) and LPG buses, respectively.

For the performance evaluation of a bus firm operating in the transportation sector [8] employed the TOPSIS approach, which is one of the MCDM methods. The study was examined with four main criteria and 14 sub-criteria, based on the financial and non-financial data of the enterprise between the years 2007-2010. As a result of the study, it was determined that the enterprise was more successful in 2007 in the four-year performance evaluation.

In their study on customer satisfaction in public transportation [9] conducted a customer satisfaction survey among passengers utilizing urban public transportation vehicles in Istanbul, and the results were analyzed using Type-2 Fuzzy TOPSIS and Gray Relational Analysis methodologies. As a result of the study, metrobus transportation was the best public transportation tool in terms of customer satisfaction.

Using the interval value fuzzy VIKOR method, which is one of the fuzzy MCDM methods used in the evaluation of performance measurements, [10] investigated the performance of three large intercity bus operators and the applicability of the method using the criteria of safety, comfort, convenience, operation, and social service. The benefits and applicability of the strategy were discovered as a result of the research.

[11] employed Entropy and TOPSIS methodologies to examine the feasibility of increasing road capacity in response to rising demand in road transportation. As a result of the study, which evaluated nine criteria using the city of Luoding as a case study, it was determined that the criteria of road passenger turnover, annual average road quality ratio, and cemented road to administrative village ratio were more important, and that these criteria were suggested to be prioritized in future studies on road capacity development.

[12] used MCDM, AHP, and TOPSIS approaches to solve automotive purchase decision problems. They used expert comments, literature reviews, and automotive guides on the manufacturers' websites to determine the major and sub-criteria. The study indicated that the vehicle's technical features and economic factors were the most important primary criteria, while safety, price, and spare parts availability were the most important sub-criteria.

[13] examined two alternative vehicles with similar features according to nine different criteria. They used the AHP method to determine the criterion weights, and the TOPSIS method to determine the best alternative. As a result of the analysis carried out with the data obtained from three experts in the study, the best alternative vehicles were listed and the most important criterion effective in vehicle selection was determined as the price criterion.

[14] aimed to determine the most suitable mode of transportation for Istanbul Airport. In the study, four alternative transportation modes (underground metro, rapid bus transit, light rail transit and premium bus) were evaluated under 14 criteria. The criterion weights were performed with the Fuzzy Level Based Weight Assessment (LBWA) method, and the ranking of the alternatives was performed with a hybrid fuzzy multi-criteria decision-making method based on the LBWA-WASPAS-H model. As a result of the study, the most suitable means of transportation was the underground metro.

[15] examined the decision problem of choosing the best shuttle bus using AHP and TOPSIS methods. In the study, it is aimed to choose the best alternative among six alternative vehicles, namely internal combustion engine vehicle, electric vehicle and hybrid electric vehicle. It had been one of the best alternative electric vehicles identified at the end of the study.

[16] evaluated the bulk vehicle selection problem of logistics enterprises using AHP and ARAS methods, using three alternatives and four criteria. As a result of the study, the best alternative tool was determined and shared with the relevant people in the sector.

A careful review of the references listed above reveals that there has been no study specifically focused on determining the most suitable bus brand for intercity passenger transport. This research specifically addresses this gap by concentrating on solving the problem of identifying the optimal bus model for intercity passenger transportation through the application of hybrid and integrated MCDM methods.

METHOD

In this study, MCDM methods, one of the quantitative research methods, were used in order to select the most suitable bus model for road travel businesses. The related decision problem was evaluated with Entropy, EDAS, WASPAS and Gray Relational Analysis methods among different MCDM methods.

RESEARCH MODEL

The research model was built in accordance with the study's goal by taking into account expert opinions and studies in numerous fields related to tool selection in the literature. Four main criteria and 16 sub-criteria were determined for the solution of the decision problem of choosing the most suitable bus model, and the most suitable one among 10 alternative bus brands was determined. The purpose of the research, its alternatives, and its hierarchical model consisting of main and sub-criteria are shown in Figure 1.

DETERMINATION OF CRITERIA AND ALTERNATIVES

The identification of criteria and alternatives is a critical step in any multi-criteria decision-making process, as it lays the foundation for a comprehensive and well-informed evaluation. In this study, relevant literature studies were taken into consideration, and criteria and alternatives were formulated based on the opinions of industry professionals to determine the optimal set for the intercity bus model selection problem. Firstly, a literature review was conducted to identify the key criteria commonly employed in similar problems within the bus and passenger transportation sector, providing a theoretical foundation. Subsequently, the practicality and suitability of the criteria and alternatives were ensured through evaluations by industry practitioners, reflecting the needs and priorities of the sector. This approach ensured the incorporation of both theoretical underpinnings and industry-specific requirements.

DATA ANALYSIS

MATLAB R2018a, and IBM SPSS Statistics 25 program were used in the analysis of the data. Each of the MCDM methods used in the study was turned into a function and analyzed by writing a code in the MATLAB program. In addition, SPSS package program was used to compare MCDM method.

MCDM METHODS USED IN THE STUDY

In the decision-making process, decision makers use methods based on mathematical models in order to achieve the best results in the shortest way and to quickly solve complex decision problems [17]. In this context, optimal solutions can be obtained with MCDM methods, which allow the evaluation of more than one criterion and alternatives in decision problems. By combining several MCDM methodologies in the decision-making process, the most appropriate options can be selected. In this study, four different multi-criteria decision-making methods are used for the decision problem of choosing the most suitable bus model. These methods are Entropy, EDAS, WASPAS and Gray Relational Analysis methods. The weight of the criteria was determined using the Entropy approach, while the optimal alternative was determined using the EDAS, WASPAS, and Gray Relational Analysis methods.

Entropy Method

Entropy is expressed as a mathematical measurement of the probability of realization of information in a system. Entropy is based on measuring the amount of information in the current index and is shown in expression (1) [18].

$$H(x) = -\sum_i p(x_i) \cdot \log p(x_i). \quad (1)$$

The entropy method is based on the principle of density of opposition. As a result, the Entropy value is affected by variances in the performance values of each option according to each characteristic. The more intense the differentiation, the greater the information transmitted. In other words, the fact that a feature contains similar information for all alternatives in the decision matrix causes the weight of the relevant feature to be less in the decision process.

Determining the criterion weights with the Entropy method in a decision problem consists of the following steps [19-21]:

Step 1: Creating the Decision Matrix

Step 2: Standardizing Values by Benefit and Cost Criteria

Step 3: Creating the Normalization Matrix

Step 4: Calculating Entropy Values

Step 5: Calculating Entropy Weights

Weighted Aggregated Sum Product Assessment (WASPAS) Method

The WASPAS method, which is one of the MCDM methods used in determining the best alternative, was developed as a new methodology by Zavadskas et al. in 2012. The WASPAS method proposes an integrated MCDM method in which two methods, the Weighted Sum Model (WSM) and the Weighted Product Model (WPM) are combined to find the most relevant solutions in a decision problem [22].

The steps followed to select the best alternative with the WASPAS method are as follows [23, 24]:

Step 1: Creating the Decision Matrix

Step 2: Normalization of the Decision Matrix

Step 3: Calculating Performances Based on the WSM Method

Step 4: Calculating Performances Based on WPM Method

Step 5: Calculating the Joint Relative Performance of Alternatives

Step 6: Calculating Grand Total Relative Performance of Alternatives and Ranking of Options

Evaluation Based on Distance from Average Solution (EDAS) Method

The EDAS method was proposed as a new methodology by [23] in the article 'Multi Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS)'. EDAS, which is one of the multi-criteria decision-making methods, is a method that has similar features with frequently used MCDM methods such as TOPSIS and VIKOR. Unlike these approaches, the EDAS method determines the best alternatives using average solution distances (Average Solution – AV) rather than the most ideal solution distances. The performances of the alternatives are calculated using two criteria in this method: Positive Distance from Average (PDA) and Negative Distance from Average (NDA).

The application steps of the EDAS method are as follows [23, 25]:

Step 1: Creating the Decision Matrix

Step 2: Determining the Average Solutions for the Criteria

Step 3: Constructing Positive-Negative Distance Matrices from Mean

Step 4: Calculation of Weighted Total SPi and SNi Values for Alternatives

Step 5: Normalizing SPi and SNi Values

Step 6: Calculating Evaluation Scores (AS) and Ranking Alternatives

Gray Relational Analysis Method

Gray Relational Analysis method is a decision-making method based on Gray System Theory, developed by Deng in 1982 [26]. In Gray System Theory, the expression 'gray' refers to understanding the system. If there is a situation in a system where the information is not known at all, the system is expressed as 'black', and if there is sufficient information, the system is expressed as 'white' [27]. Gray Relational Analysis uses this situation to determine the correlation of similarities and differences between the reference series in a system and the factor series to be compared [28].

The application steps of the gray relational analysis method are as follows [29]:

Step 1: Creating the Decision Matrix

Step 2: Creating the Reference Series

Step 3: Creating the Normalization Matrix

Step 4: Creating the Absolute Value Table

Step 5: Creating the Gray Relational Coefficient Matrix

Step 6: Calculating Gray Relational Grades and Ranking Alternatives

FINDINGS AND COMMENTS

The choice issue of determining the best appropriate bus type for intercity passenger transportation was chosen for the study. Data were collected from travel operators at the intercity bus terminal in Istanbul. The collected data was used to create the basic decision matrix for the selection problem.

In the decision matrix created, considering the criteria codes of the sub-criteria and the cost and benefit aspects of each criterion, the direction of the criteria was expressed as 'min.' and 'max.', respectively. Determined evaluation criteria were given in Table 1.

Table 2 lists the alternatives identified in the study, along with their alternate codes.

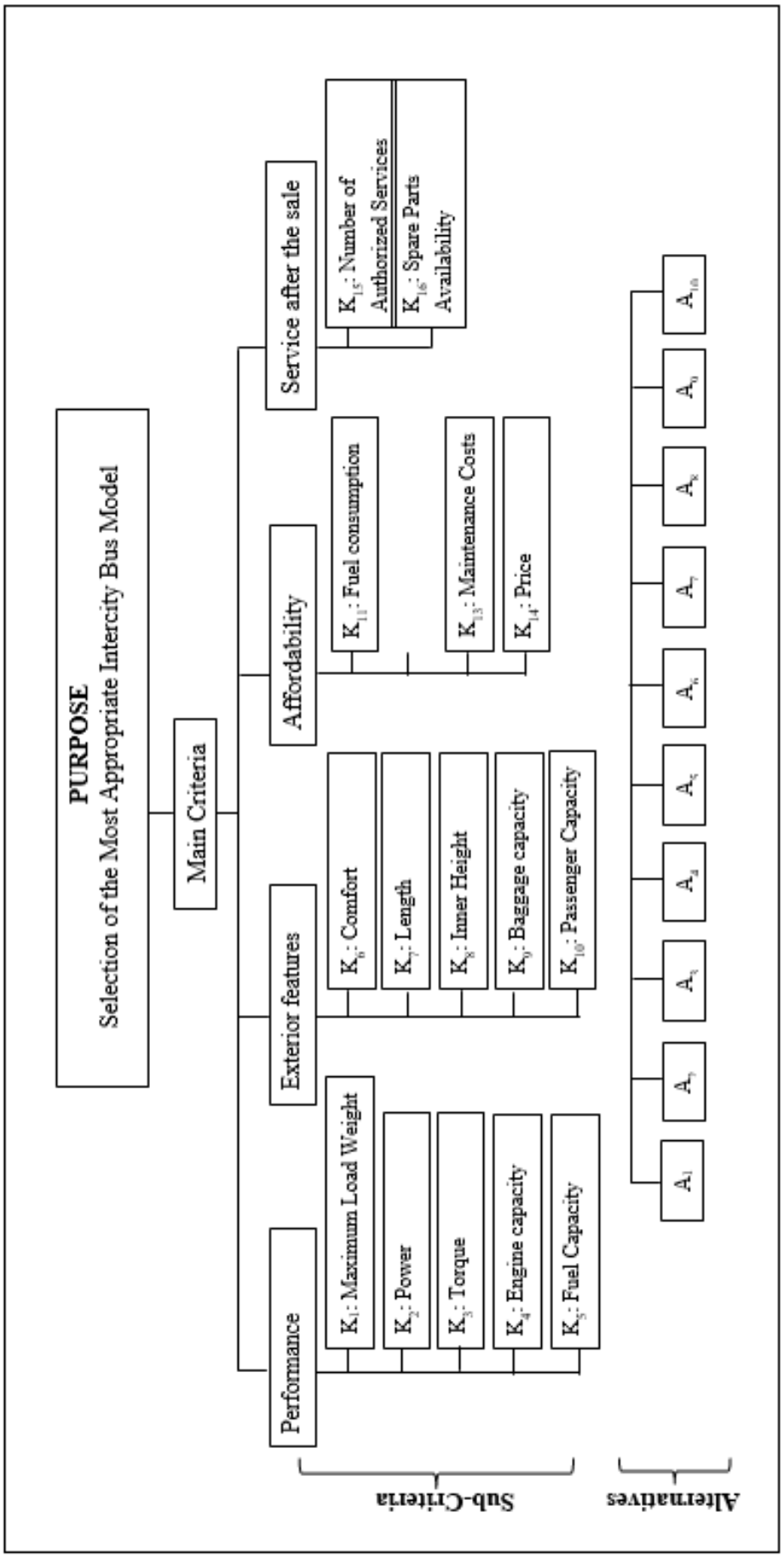

Figure 1. Bus selection model for intercity passenger transport.

Table 1. Criteria used in the study.

Main Criteria	Sub-Criteria	Criteria Code	Direction of Criteria
Performance	Maximum Load Weight, kg	K_1	Max
	Power, HP	K_2	Max
	Torque, Nm	K_3	Max
	Engine capacity, cm^3	K_4	Max
	Fuel Capacity, *L*	K_5	Max
Exterior features	Comfort	K_6	Max
	Length, mm	K_7	Min
	Inner Height, mm	K_8	Max
	Baggage capacity, m^3	K_9	Max
	Passenger Capacity	K_{10}	Max
Affordability	Fuel consumption, *L*/100 km	K_{11}	Min
	Guarantee Period, Year	K_{12}	Max
	Maintenance Costs, TL	K_{13}	Min
	Price, TL	K_{14}	Min
Service after the sale	Number of Authorized Services	K_{15}	Max
	Spare Parts Availability	K_{16}	Max

Table 2. Alternatives used in the study.

Alternative	Code of Alternative
Mercedes-Benz Tourismo (15 RHD, 2+2)	A_1
Mercedes-Benz Tourismo (16 RHD, 2+2)	A_2
Mercedes- Benz Travego (15 SHD 2+2)	A_3
Mercedes- Benz Travego (16 SHD 2+1)	A_4
Neoplan Tourliner (2+1)	A_5
Neoplan Cityliner (2+1)	A_6
Otokar- Doruk T (2+2)	A_7
Temsa Maraton 12 (2+1)	A_8
Temsa Safir Plus (2+1)	A_9
Man Lion's Coach C (2+1)	A_{10}

CALCULATION OF CRITERION WEIGHTS BY ENTROPY METHOD

Technical and hardware features are the majority of the factors utilized in the decision problem to determine the best bus type. Therefore, it was observed that it will be difficult for decision makers to evaluate these criteria subjectively. For this reason, it was concluded that it would be appropriate to evaluate the criteria objectively in order to reach more accurate results, and the Entropy method was preferred as the objective weighting method in determining the importance levels of the criteria.

By employing the Entropy method, decision-makers can objectively capture the inherent information content and variability present in the decision matrix, ensuring that the resulting criteria weights accurately reflect the relative importance of each criterion in the decision-making process. It is important to note that the interpretation of Entropy results should be contextualized within the specific decision problem. Higher weights assigned to certain criteria indicate their greater discriminating power and potential impact on the final ranking or selection of alternatives. Decision makers can use these weights to prioritize and focus on the most influential criteria during the subsequent stages of the decision making process.

The entropy approach was used in six phases to determine the weights of the criterion. However, due to the length of the expression of all processes in the research, it was summarized. First of all, the Decision Matrix was expressed in Table 3.

Table 3. Decision Matrix.

	Max	Max	Max	Max	Max	Max	Min	Max	Max	Max	Min	Max	Min	Min	Max	Max
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16
A1	18000	349	1600	11967	493	4	12140	2010	8,2	50	24	2	3107	1800000	23	8
A2	24000	422	2100	11967	507	5	13190	2010	10,8	54	24.5	2	3107	2200000	23	8
A3	18000	428	2100	10677	480	6	12180	2100	10,7	46	27	2	3098	2180000	23	8
A4	24000	335	2200	10677	480	8	13115	1950	14	41	27	2	3200	2240000	23	8
A5	18000	420	2100	12419	525	6	12113	2250	12	41	21.5	2	2075	1800000	31	5
A6	18000	430	2200	12419	480	8	12240	2066	12,2	41	21.5	2	2075	1700000	31	5
A7	10000	254	1317	6700	350	3	10100	1986	5,5	43	27.5	2	1500	1571000	20	2
A8	18000	449	2300	10800	583	7	12365	2000	12	53	26.5	3	2500	1720000	50	6
A9	18000	435	2100	10800	583	6	12276	2000	10	50	21.5	3	2600	1801000	50	6
A10	17000	460	2300	12419	480	8	13091	2006	14,3	41	24	2	2075	1910000	31	5

Table 4 shows the weights of the criteria achieved by progressing through the Entropy Method's analysis phases.

Table 4. Criterion weights.

Main Criteria	Sub-Criteria	Weight	Rank
Performance	Maximum Load Weight, kg	0,069	6.
	Power, hp	0,043	8.
	Torque, Nm	0,041	9.
	Engine capacity, cm^3	0,041	10.
	Fuel Capacity, *L*	0,029	11.
Exterior features	Comfort	0,121	3.
	Length, mm	0,013	15.
	Baggage capacity, m^3	0,090	5.
	Inner Height, mm	0,007	16.
	Passenger Capacity	0,023	13.
Affordability	Fuel consumption, *L*/100 km	0,018	14.
	Guarantee Period, Year	0,051	7.
	Maintenance Costs, TL	0,097	4.
	Price, TL	0,024	12.
Service after the sale	Number of Authorized Services	0,167	1.
	Spare Parts Availability	0,165	2.

When the criterion weights determined by the Entropy method in Table 4 were examined, it was seen that the most important main criterion for the selection of the most suitable intercity bus model is "Service After the Sale". The three criteria with the highest degree of importance were the Number of Authorized Services (K15), Availability of Spare Parts (K16), Comfort (K6), and the criterion with the lowest degree of importance was the Interior Height (K8) criterion.

RANKING ALTERNATIVES WITH WASPAS

The WASPAS approach, which combines two methods, WSM and WPM, is a popular choice for addressing decision problems that need only a few calculations. The phases of the technique were followed by examining the cost-benefit conditions of each criteria in the decision matrix, and they are listed further in the text. Because the tables take up too much space, only the result-oriented Table 5 and the related comment were expressed.

Table 5. Final performances of alternatives where λ = 0,5.

Alternative	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
Performance	0,673	0,734	0,725	0,776	0,743	0,773	0,487	0,852	0,818	0,782
Rank	9.	7.	8.	4.	6.	5.	10.	1.	2.	3.

When Table 5 was examined, it was seen that the best three alternatives were A_8 (Temsa Maraton 12 (2+1)), A_9 (Temsa Safir Plus (2+1)), A_{10} (Man Lion's Coach C (2+1)), respectively.

RANKING ALTERNATIVES WITH EDAS

After determining the performance of the alternatives using the WASPAS approach, the same problem was examined using the EDAS method in the research. The EDAS approach, which uses average solution distances to quantify the performance values of choices in a decision issue, was a novel MCDM method that was widely utilized due to its straightforward and easy calculation processes. The table and its interpretation were simplified here because the whole EDAS procedure, which comprises of seven phases, was too long for the research.

In the last step of the method, the evaluation scores of the alternatives were calculated for the final ranking. AS scores of alternatives were calculated. Half of the sum of the NSP and NSN values for each alternative also gives the AS values. For example, AS scores for A_3 and A_4 alternatives were calculated as follows;

$$\mathrm{AS}_3 = \frac{1}{2}\left(\mathrm{NSP}_3 + \mathrm{NSN}_3\right) = \frac{(0.323+0.782)}{2} = 0.552, \tag{2}$$

$$\mathrm{AS}_4 = \frac{1}{2}\left(\mathrm{NSP}_4 + \mathrm{NSN}_4\right) = \frac{(0.795+0.755)}{2} = 0.775. \tag{3}$$

As a result of the final ranking scores determined, the options are listed in the descending order in Table 6.

Table 6. AS scores and final ranking of alternatives.

Alternative	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
AS	0,468	0,613	0,552	0,775	0,570	0,690	0,132	0,991	0,881	0,735
Rank	9.	6.	8.	3.	7.	5.	10.	1.	2.	4.

As a result of the EDAS method, the option with the highest AS score was selected as the best alternative. When the final results in Table 8 are examined, it was seen that the A_8 alternative has the highest score. The three best alternatives determined according to the EDAS method were A_8 (Temsa Maraton 12 (2+1)), A_9 (Temsa Safir Plus (2+1)), A_4 (Mercedes-Benz Travego (16 SHD 2+1)), respectively. It was seen that the score values are close to each other in the ranking, and the A_7 alternative with the most difference was the option with the lowest score.

RANKING OF ALTERNATIVES WITH GRAY RELATIONAL ANALYSIS METHOD

The Gray Relational Analysis technique was the third MCDM approach utilized for the choice issue of finding the best suitable bus model in the research. Gray relational Analysis is an MCDM approach that attempts to measure information based on the reference information stored in a system. It is widely used in a variety of fields. Compared to existing methodologies, the GRA method is a method that can produce reliable results and provides good discrimination between options. The analysis results of the Gray Relational Analysis method are summarized further in the text.

In the last step of the gray relational analysis method, Weighted Gray Relational Ranks were calculated by multiplying the gray relational coefficients with the criterion weights determined by the Entropy method. The determined Gray Relational Degrees were ordered from largest to smallest and the most ideal option was determined. The gray relational degrees determined, and the order of the alternatives were given in Table 7.

Table 7. Weighted gray relational grades and ranking of alternatives.

w_j	0.07	0.04	0.04	0.04	0.02	0.12	0.01	0.01	0.09	0.02	0.02	0.05	0.10	0.02	0.17	0.17		
	K_1	**K_2**	**K_3**	**K_4**	**K_5**	**K_6**	**K_7**	**K_8**	**K_9**	**K_{10}**	**K_{11}**	**K_{12}**	**K_{13}**	**K_{14}**	**K_{15}**	**K_{16}**	**Γ_{0i}**	**Rank**
A_1	0.5	0.5	0.4	0.9	0.6	0.4	0.4	0.4	0.4	0.6	0.6	0.3	0.4	0.6	0.4	1.0	0.5	9
A_2	1.0	0.7	0.7	0.9	0.6	0.5	0.3	0.4	0.6	1.0	0.5	0.3	0.4	0.4	0.4	1.0	0.6	6
A_3	0.5	0.8	0.7	0.6	0.5	0.6	0.4	0.5	0.6	0.5	0.4	0.3	0.4	0.4	0.4	1.0	0.6	8
A_4	1.0	0.5	0.8	0.6	0.5	1.0	0.3	0.3	0.9	0.3	0.4	0.3	0.3	0.3	0.4	1.0	0.7	3
A_5	0.5	0.7	0.7	1.0	0.7	0.6	0.4	1.0	0.7	0.3	1.0	0.3	0.6	0.6	0.4	0.5	0.6	7
A_6	0.5	0.8	0.8	1.0	0.5	1.0	0.4	0.5	0.7	0.3	1.0	0.3	0.6	0.7	0.4	0.5	0.6	5
A_7	0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.4	0.3	0.4	0.3	0.3	1.0	1.0	0.3	0.3	0.4	10
A_8	0.5	0.9	1.0	0.6	1.0	0.7	0.4	0.4	0.7	0.9	0.4	1.0	0.5	0.7	1.0	0.6	0.7	1
A_9	0.5	0.8	0.7	0.6	1.0	0.6	0.4	0.4	0.5	0.6	1.0	1.0	0.4	0.6	1.0	0.6	0.7	2
A_{10}	0.5	1.0	1.0	1.0	0.5	1.0	0.3	0.4	1.0	0.3	0.6	0.3	0.6	0.5	0.4	0.5	0.7	4

For example, the gray relational degree for alternative A_1 was calculated as follows:

$$\Gamma_{01} = \sum_{j=1}^{16} w_1(j) \cdot \gamma_{01}(j) = 0{,}54 \cdot 0{,}069 + 0{,}48 \cdot 0{,}043 + 0{,}41 \cdot 0{,}041 + 0{,}86 \cdot 0{,}041 +$$
$$+0{,}56 \cdot 0{,}121 + 0{,}38 \cdot 0{,}121 + 0{,}43 \cdot 0{,}013 + 0{,}38 \cdot 0{,}007 + 0{,}42 \cdot 0{,}09 + 0{,}62 \cdot 0{,}023 +$$
$$+0{,}55 \cdot 0{,}018 + 0{,}33 \cdot 0{,}051 + 0{,}35 \cdot 0{,}097 + 0{,}59 \cdot 0{,}024 + 0{,}36 \cdot 0{,}167 + 1{,}00 \cdot 0{,}165$$
$$= 0{,}53. \quad (4)$$

The gray relational degrees calculated here were expressed as a criterion that shows the relationship between the reference series (x_0^*) and the comparable series (x_i^*), allowing the series to be compared. It was accepted that the relationship between (x_0^*) and (x_i^*) was strong when the gray relational degrees were large. If the gray relational degree was 1, it was stated that the compared series are the same.

COMPARISON OF WASPAS, EDAS AND GRAY RELATIONAL ANALYSIS METHODS

In this study, the decision problem of determining the most suitable bus model for travel businesses was examined. Significant results were obtained by using different MCDM methods together to determine the best alternative among bus models with similar features. Alternatives to the relevant decision problem were evaluated with WASPAS, EDAS and Gray Relational Analysis methods, and the final rankings are given in Table 8 comparatively.

When the ranking results of the methods are examined, A8 alternative was the first best alternative and A9 was the second-best alternative as a result of WASPAS, EDAS and Gray Relational methods. Finally, the relationship between the methods used in the study and the obtained rankings was evaluated by Spearman Rank Correlation Analysis.

Spearman Rank Correlation (Spearman Rho Correlation Coefficient), as a statistical test, is used to determine the relationship between two variables when the distribution is not normal, measured with a rank scale. While determining the correlation coefficient, the calculation was made on the ordinal numbers of the data and this coefficient takes values ranging from –1 to +1. The formula used in the calculation of Spearman Rank Correlation was as follows [30]:

$$r_s = 1 - \frac{6 \sum d^2}{N(N^2-1)}, \quad (5)$$

with variables: N – the number of units in the population or sample, d^2 – the square of the order differences between the two variables and r_s – Spearman rank correlation coefficient.

Table 8. Comparison of WASPAS, EDAS and gray relational analysis methods.

	WASPAS		EDAS		GRA	
Alternative	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
A_1	0,673	9.	0,468	9.	0,533	9.
A_2	0,734	7.	0,613	6.	0,611	6.
A_3	0,725	8.	0,552	8.	0,567	8.
A_4	0,776	4.	0,775	3.	0,672	3.
A_5	0,743	6.	0,57	7.	0,568	7.
A_6	0,773	5.	0,69	5.	0,626	5.
A_7	0,487	10.	0,132	10.	0,424	10.
A_8	0,852	1.	0,991	1.	0,731	1.
A_9	0,818	2.	0,881	2.	0,683	2.
A_{10}	0,782	3.	0,735	4.	0,654	4.

IBM SPSS Statistics 25 program was used to calculate the correlation coefficients. The results of the analysis are presented in Table 9.

Table 9. Correlation relationship between obtained performance values.

Spearman rank correlation					
			EDAS	WASPAS	GRA
Spearman's rho	EDAS	Correlation Coefficient	1,000	0,976**	1,000**
		Sig.	.	0,000	.
		N	10	10	10
	WASPAS	Correlation Coefficient	0,976**	1,000	0,976**
		Sig.	0,000	.	0,000
		N	10	10	10
	GRA	Correlation Coefficient	1,000**	0,976**	1,000
		Sig.	.	0,000	.
		N	10	10	10

**significant at the 0,01 significance level (2-way)

When Table 11 is examined, it is seen that there is a positive relationship between the methods used and the results achieved. It is seen that the performance ranking results of the Entropy-based EDAS, WASPAS and GRA methods used contain very close values. When the Spearman Rank Correlation values of the methods is examined, r_s = 0,976 between the WASPAS and EDAS methods, and it is seen that there is a positive linear relationship at the 99 % confidence interval between the rankings of the methods for the bus models.

CONCLUSION AND EVALUATION

In this study, a selection model for the buses used in intercity passenger transportation was proposed, which could be used by travel companies and those concerned in the sector. Also, the decision processes of travel businesses to purchase new buses were tried to be evaluated with scientific methods. In the study, the decision problem of choosing the most suitable bus model was analyzed with different MCDM methods, so it was aimed to fill the gap in this field in the literature with the sample application.

First of all, a detailed literature review was made, and the criteria used in vehicle selection were examined in detail. Then, as a result of one-on-one interviews with the expert team working as

a manager in travel businesses in Istanbul, alternatives and criteria that could be effective in the bus purchasing processes of travel businesses were determined. Entropy method, which was an objective weighting method, was used in calculating the importance levels of four main and 16 sub-criteria determined for the most suitable bus model selection. When the weight values of the criteria performed by the entropy method were examined, the "number of authorized services" criterion had the highest value. While the second criterion was "spare parts availability", the third criterion was "comfort".

As a result of the analyzes carried out with all three methods, the "Temsa Maraton 12 (2+1)" bus model was determined as the first alternative, and the "Temsa Safir Plus (2+1)" bus model was determined as the second alternative. The relationship between the rankings obtained as a result of the analysis of the study was compared with the Spearman Rank Correlation Analysis and positive significant results were obtained. It was thought that a more effective and efficient supply would be realized if the model created in the study was used as an example by the enterprises in the new bus purchase decision processes of intercity travel enterprises.

Albini et al. [31] in their study advocated for the establishment of a standard in the new categorization of vehicle automation. The study [31] examines technologies developed for this purpose according to the new categories and functional layers of the general IT infrastructure. However, the present study aims to determine the most suitable bus brand among vehicles used in intercity passenger transportation, employing integrated MCDM (Multi-Criteria Decision Making) methods.

Temesvári and Maros [32] aim to estimate the necessary data transfer rate and the amount of increase in data usage over the next few years to support emerging mobile technologies, based on previous research and the analysis of broadband mobile networks. The Internet of Things, Machine-to-Machine Communication, Smart Cities, and the inability of existing mobile networks to handle high traffic volumes have been taken into consideration [32]. However, this study aims to determine the optimum bus brand with desirable features for passenger transportation. In these aspects, it differs from the aforementioned study.

The study by Vahdani, Zandieh, and Tavakkoli-Moghaddam [7] introduce innovative fuzzy multiple criteria decision-making (FMCDM) methods for selecting alternative-fuel buses, employing fuzzy logic and linguistic variables to handle the inherent uncertainties in evaluating different fuel types, such as electricity, hydrogen, and methanol. Their approach, which integrates fuzzy TOPSIS and an extended fuzzy preference selection index method, provides a refined mechanism for ranking alternatives by accommodating the imprecision and subjectivity in decision criteria [7]. This study employed integrated Multi-Criteria Decision-Making methods, including the Entropy method, to evaluate bus selection. It weighted criteria such as service availability, spare parts availability, and comfort, ultimately determining the optimal bus models based on these quantitative measures.

It was discovered that the study's procedures for choosing the most appropriate bus model were consistent. Different MCDM approaches, on the other hand, might be utilized in comparable research in the future. As a result, the impact of the applied methods on the rankings could be thoroughly investigated. Furthermore, with today's extensive usage of chain markets and e-commerce sites, courier and package services had become increasingly vital. As a result, research might be conducted to determine the best appropriate light commercial vehicles, panel vans, or motorbikes.

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DESIGN AND MANUFACTURING OF A SIMPLE SOFT CATERPILLAR ROBOT

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ABSTRACT

Soft robots are increasingly gaining attention not only within the scientific community, but also in various real-world applications, due to their inherent compliance, ease of manufacture and favourable mechanical properties. These robots can manipulate a wide range of objects without the need for precise feedback on position, orientation, force, and torque. Their low elastic moduli make them inherently safe. However, although the field of soft robotics has been well established now, there is still a significantly smaller number of successfully realized applications in the domain of mobile soft robotics.

This article presents a detailed development process of a tethered mobile caterpillar-like soft robot. A single part mould is designed and used to cast the silicone body of the robot with integrated four Shape Memory Alloy tendons, allowing generation of the inching motion pattern. The detailed analysis of the manufacturing process for robot fabrication, with the necessary hardware and software used for robot control is presented. Experimental verification shows usability of presented approach, but also reveals limitations mainly due to insufficient cooling of the Shape Memory Alloy tendons which limits the number of cycles per time.

KEY WORDS

soft robot, shape memory alloy, biomimetic robot, soft robot manufacturing process

CLASSIFICATION

JEL: L69

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INTRODUCTION

Soft robotics is an increasingly growing interdisciplinary field that focuses on the design and manufacture of robots made from soft materials. The field is combining robotics, chemistry, and mechanics of materials to enable the preprogramming of the function – complex motion into flexible, soft materials [1, 2]. As the robot considered here is a mechatronic device, interdisciplinarity is understood, considering mechatronics itself consists of mechanics and electronics. Indeed, the article deals with both detailed mechanics (the movement of the robot) and electronics (through it circuits, relationship between electrical parameters and movement). Furthermore, the article deals with material science as well as one of the key considerations of a soft robot is its material (therefore "softness"), and a high degree of detail has been discussed. Lastly, as the manufacturing process is described in detail as well, the article includes considerations of manufacturing science.

Also, the article includes a detailed description of the manufacturing process of the robot, which can be reproduced, it can also be considered as part of citizen science. This allows the possibility for different volunteers all over the world to recreate the experiment. Citizen science can be used as a way to gather, where different volunteers can recreate the robot and perform experiments with different robot shapes or electrical parameters, and thus reporting it's influence on the results.

The term soft is related to materials with Young's modulus in the range ~ $[10^4 – 10^9]$ Pa, which is comparable to biological tissues such as skin, muscles, and to a lesser extent bone. Traditional robots made of metal alloys have elastic moduli in the range ~ $[10^9 – 10^{12}]$ Pa. Engineering materials such as silicones, hydrogels, rubber, thermoplastics, fit well into the range of soft materials which makes them suitable for soft robotics applications [3]. The actuation of these soft structures can be achieved by various stimuli, including pressure of fluids, both pneumatics and hydraulics, electrical charges, chemical reactions, shape memory alloys, and magnetic effects [4, 5].

Despite significant interest the field is gaining, there is still area for more theoretical studies and successful applications in the field of mobile soft robots. The main limiting factor for successful applications of mobile soft robots identified is low energy efficiency [6]. There are several applications indicating further limitations of current approaches in mobile soft robotics, as well as potential improvements, and research directions.

Trimmer et al. formulated the general principles of soft bodied robots inspired by motion of animals such as worms and caterpillars [7]. SMAs (Shape Memory Alloy) have been successfully applied to generate six gaits based on constraints imposed by the structure of the soft robots' body. Theoretical foundations for successful translation of locomotion patterns of animals to biomorphic robots have been proposed.

Seok et al. have explained the properties and production of NiTi (nickel-titanium) SMA actuators [8], which they have used in the soft robot with multiple contractile segments undergoing peristaltic crawling locomotion. They have proven their robot can withstand a hit with a rubber hammer without suffering any damage. Furthermore, Luo et al. have used fluidic elastomer actuators (FEA) to move their soft robot [9]. They have provided three distinct types of actuators, and whilst they have shown satisfactory results in controllability and speed, their disadvantage is a delay in response in release time (due to the fluid), which also varies with tube length. However, the main advantage is that they do not overheat (which is an issue soft robot with SMA actuators face) so they can work consistently for longer times.

Pfeil et al. used dielectric elastomer actuators (DEA) to create crawling motion in their soft robot [10]. Additionally, Munadi et al. have developed a motor-tendon actuator for their

starfish-like soft robot [11], which achieves motion by a servo motor pulling a tendon. Chua and Yeow have used air propulsion to achieve locomotion in their air-driven soft robots [12]. Their robot can crawl, pinch, grasp and kick while powered from a pneumatic source.

Furthermore, one of the key issues soft robots face is storing power (to keep them autonomous), as conventional power sources which give autonomy such as batteries, pneumatic or hydraulic cylinders all bring rigidity, which will compromise the robot's softness. Mc Caffrey et al. offer a solution for the soft robot's autonomy by introducing magnetic coupled wireless power transfer on their caterpillar-based soft robot [13]. Their worm-like soft robot also utilizes SMA.

Regarding the topic of motion of soft robots, Calisti et al. give an overview of diverse types of soft robot locomotion (such as worm-like, serpentine, or peristaltic crawling and even swimming and flying for non-surface soft robots) [14], noting their pros and cons. All these types of locomotion draw their inspiration from nature. For example, Marchese et al. have developed a fish-like robot, with rapid body motions [15]. While their fish-like robot demonstrated impressive handling capability, part of its body is fully rigid, offering a place for conventional supporting rigid hardware, thus not being considered a fully soft robot. Furthermore, Joshi et al. designed a jellyfish-inspired soft robot [16]. The inflation of their robot alone was not enough to yield floating due to the weight it was carrying, so a swimming motion needed to be induced to move upwards. It would produce a swimming motion, actuated by fluidic actuators. Their robot was capable of manoeuvring in a water tank, although without full autonomy as it is powered by an external power supply. Zhang et at. have developed a worm-like soft robot capable of manoeuvring in complicated tubular environments [17], such as a pipeline with differing diameters. Their robot has shown strong environmental adaptability, being able to pass through complex constrained environments. A similar approach is presented in [18] by Lin et al., with a unidirectional soft robot based on a standard McKibben pneumatic actuator and custom 3D printed tentacles that enable very reliable motion in confined spaces like pipes with variable cross sections and curvatures. Wang et al. have incorporated rapidly exploring random-tree algorithm-based path planning [19], which makes the robot decide whether to continue forward or to back-up before manoeuvring.

Kandhari et al. have developed fabric-based soft robots [20], which have several advantages, mostly in the future development of wearable robotic devices (such as gloves). They have designed two robots, a larger one called "FabricWorm" which still has some rigid 3D printed parts and a smaller soft robot called "MiniFabricWorm", where the only rigid parts are conventional actuators which, by shortening or extending the cable, create the motion of the robot. They have compared their results to their previous, conventional non-fabric soft robot. Conventional actuators were used, meaning they do not face the time delay (as the FEA-based soft robots do) or the overheating issues (as the SMA-based soft robots do), however this means they do retain a degree of rigidity, which is not in perfect agreement with the idea of soft robotics. Additionally, the fabric-based robots have shown a large dependency on the surface (and the friction coefficient of the given surface). For example, when introduced to carpet the soft robot cannot effectively move. This could be addressed by adding small metal feet on the belly-side of a worm-like soft robot. Finally, the fabric-based soft robots have proven to be very costly to assemble. In contrary, Joyee et al. have designed a fully 3D printed soft robot [21], which does not require any assembly. However, the benefits of fully 3D printing are questionable for a larger production run, comparing the cost of 3D printing every single robot with the lower cost of a single 3D printed mould and subsequent silicone pouring.

Besides all the previously mentioned advances and limitations of different approaches used to materialize mobile soft robots, there is still a need for experimental verification of methods and materials used in their realization. If one wants to replicate a soft robot model, a concise and detailed process should be presented to allow for replication and comparison. In this article, a

focus is set on availability of materials used to manufacture the robot. Detailed analysis of process variables (input voltage, temperature, elastic properties of materials used), and limitations they impose on motion behaviour is presented. A whole procedure from the mould design, SMA placement, silicon application, necessary hardware and software is given in details. This will allow simple replication and further development of similar applications and enable the usage in educational and research environments.

MATERIALS AND DESIGN OF CATERPILLAR ROBOT

The focus of the proposed soft robot is on simplicity, as it is made with fewer elements than any other soft robot presented in the literature review. Also, it can be easily (re)produced in a shorter time with the straightforward and simple manufacturing process.

The choice of actuators is one of the defining features of a soft robot. Two different SMA wires were chosen as actuators, as shown in Table 1. NiTi SMA were chosen as actuators, with a 1:1 ratio of nickel and titanium. The ratio is particularly important, as a slight change in the ratio can move the temperature range by a considerable amount. They come from the factory in 10 mm length, fully compressed. When extended, it becomes 180 mm long. When in this extended shape, the actuators are cut in four equal parts and are used as such. This way four equal actuators are installed in the soft robot, working in two pairs.

Table 1. Specifications of SMA wires used in experiment.

Kellog's Research labs SMA		
Property	**NiTi SMA Wire**	
	Specimen #1	**Specimen #2**
Coil spring diameter, mm	2,4	3,2
Wire diameter, mm	0,25	0,25
Activation temperature, °C	80	80
Coil pitch, mm	0,25	0,25
Length, mm	10	10

When an electrical current is introduced, the alloy is heated and its diameter increases, which results in a contraction in length. As the SMA contracts a force is generated, which lifts the body of the soft robot. This is the basic movement which this soft robot relies on. The soft body of the robot is made from silicone, which is poured into a 3D printed mould. The actuators are set in place and the silicone is poured over it, thus incorporating it into the body of the robot. A detailed description of the materials, production technique and the robot's performance are provided. The production process of the soft robot begins with the mould. The mould is designed as negative of desired robot shape. Catia V5 R20 is used as a CAD platform, since many previous designs of soft actuators are successfully modelled in this environment and transferred to Abaqus for hyperelastic material simulations [22].

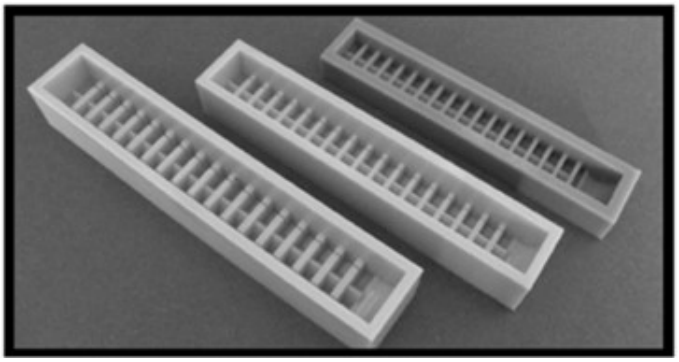
Once the model is fully defined and finished, it is subtracted from a cuboid, which corresponds to the external dimensions of the mould. After the subtraction, the remaining part is finally the mould. One last operation is necessary, to add a small channel to hold the actuator wires during the pouring of the silicone.

The mould is 3D printed with Polyjet technology and presented in Figure 1. During research, different moulds were produced, to test and compare different sized robots. With the mould created, the next step is setting the actuators in place before pouring the silicone. This means preparing the electrical connections. The temperature at which the chosen NiTi SMA contracts

is less than 100 °C, meaning they cannot be soldered due to even the lowest soldering temperatures being too high, thus highly likely to damage the SMA.

However, the connection still needs to be solid and to provide high electrical conductivity. Therefore, a mechanical connection was chosen. A custom-made connector solution is proposed, based on a M2 screw and the corresponding nut. A 0,7 mm hole was drilled close to the head of the screw, through which the SMAs are routed. They are then held in place by the M2 nut, and finally the electrical wires are soldered on the screw. With the 3D-printed mould ready, and the wiring completed, the pouring of the silicone into the mould can begin. The actuators are set into the mould, as shown in Figure 2. The choice of silicone is important, as it defines the mechanical properties of the soft robot's body, such as tensile strength and hardness.

a)



b)

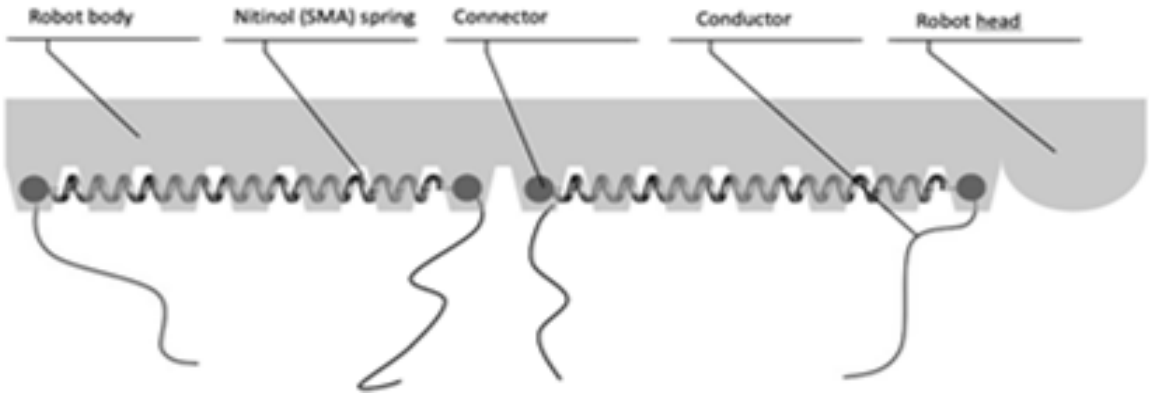


Figure 1. a) Different 3D printed moulds used for experiments, b) robot model with components.

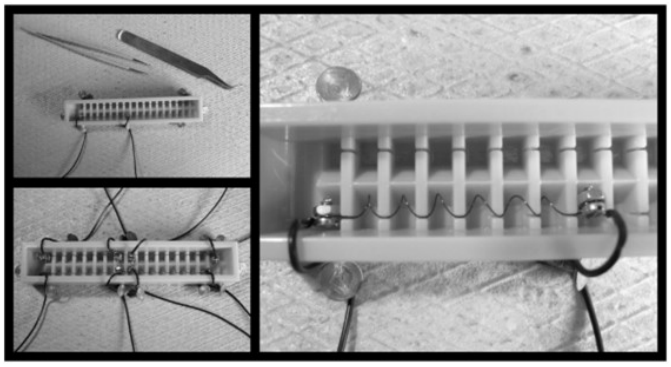


Figure 2. Actuators being set into the mould, before the pouring of the silicone mixture.

Research conducted in similar studies has shown similar robots were made from Ecoflex 00-30 or Ecoflex 00-35 two-part silicone. These products have proven popular due to their favourable mechanical properties – large elongation and low elastic modulus. The mechanical properties between the two products are similar, with the biggest difference being in cure time and pot life (the time from mixing the two components together to the point at which the mixed product is no longer usable).

In our study, upon evaluating several alternative but comparable silicone materials, an alternative silicon base has been selected. ALPA-SIL MF3 is comparable in terms of mechanical properties, with a clear advantage in terms of price. Table 2 shows the mechanical properties of the compared silicones, as per manufacturer.

As seen in Table 2, the chosen silicone alternative shows suitable properties. The significant difference between Ecoflex and ALPA SIL is in elongation and tensile strength. Alpa SIL is a material with higher elastic modulus compared to Ecoflex, and this has proven as a limiting factor. It limits the bendability of the robot, measured as the deformation of robot's body per force generated by the muscle wires. The consequence is reduced distance travelled per cycle. While it has a lesser maximum elongation, it shows better tensile strength and tear resistance.

Table 2. Comparison of silicone rubber options.

Property	Ecoflex 00-30	Ecoflex 00-35	ALPA-SIL MF3
Mix ratio by weight	1A:1B	1A:1B	100A:10B
Specific gravity, g/cm^3	1,07	1,07	1,1
Pot life, min	45	2.5	60
Cure time	4 h	5 min	16 h
Hardness, Shore A	30	35	28
Mixed viscosity, Pa·s	3	3,5	15
Elongation, %	900	900	600
Tensile strength, MPa	1,38	1,38	7,5
Tear resistance, N/mm	6,65	6,65	20

The A and B components of the silicone are mixed in the ratio of 1:10. The mixing is measured by weight, with 1 g of component A used with 10 g of component B. A thin nozzle is used to inject the mixture, with the use of a thin nozzle being especially important to fill the smallest gaps in the 3D printed mould.

The silicone then cures for 16 hours and can be extracted easily from the mould as illustrated in Figure 3. With the body separated and the actuators already in place, only one last step remains: the insertion of small metal legs or tail skids. The tail skids are used to give the robot support when lifting its body, as to successfully finish a meaningful movement. Without them, in many cases the robot did not actually move relative to the starting position at the end of a motion cycle. As the silicone is soft, the tail skids can easily be inserted in the body, even when the silicone is fully cured.

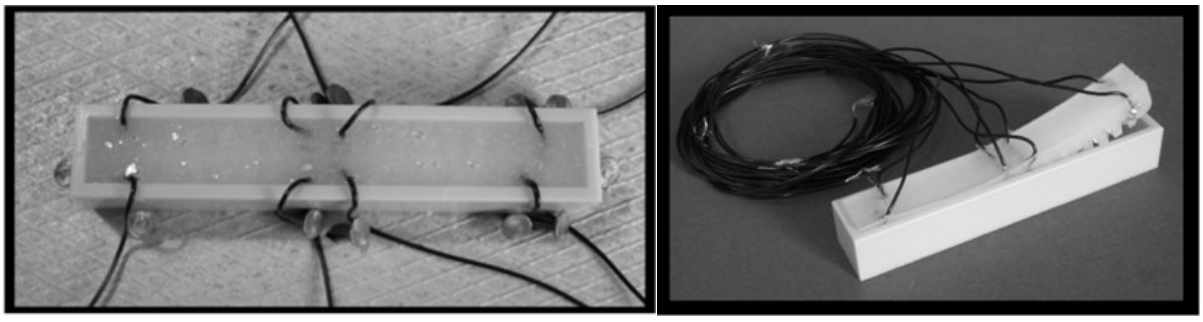


Figure 3. Curing of the silicone and the subsequent removal of the robot from the mould.

The robot is controlled using a microcontroller, connected to the robot by transistors, Figure 4. The microcontroller used is an Arduino Uno, connected to a PC via USB connection, whilst the chosen transistors are MOSFET IFR540. A KB817 optocoupler (OC_1) is utilized. The output from the microcontroller is limited to 5 mA current which is received by the optocoupler to separate positive side of the microcontroller from the power supply.

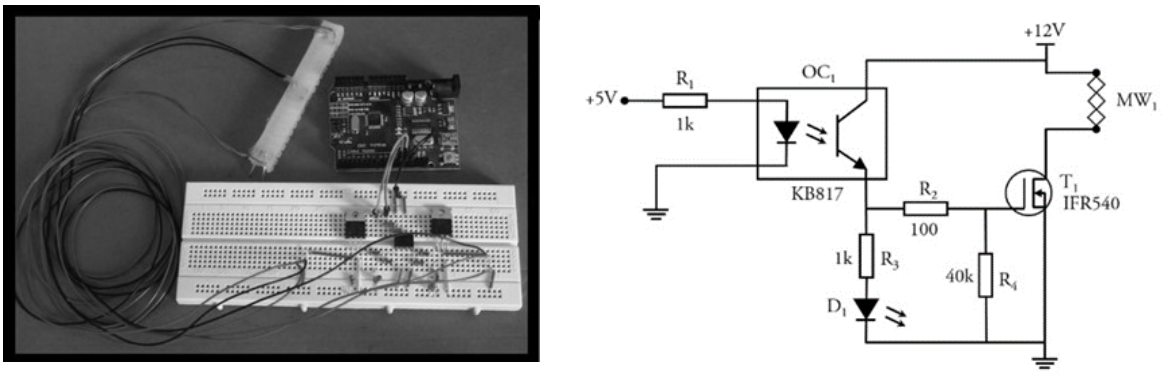


Figure 4. Equipment used for robot motion control.

The optocoupler is used as a means to protect the control electronics (the microcontroller and the PC) from an overvoltage coming from the robot, as the robot could be exposed to many different adverse operating conditions, such as proximity to active non-isolated electrical wires or strong electrical fields, it is important to protect the control electronics from any potential negative effects.

Digital signal from the optocoupler turns the transistor IFR540 (T_1) ON over the base where the transistor acts like a switch. Transistors are utilized as they use a small current or voltage source (the microcontroller) to control a larger current source needed to produce enough current to make the SMAs contract. The microcontroller turns ON the transistors with a few milliamperes which feed the current through the NiTi actuators. The intervals of conduction are predefined data in the microcontroller which instructs it on how to move the robot, what the conduction time of the SMA for a given flexion and thus movement is, stored in the memory of the microcontroller. Figure 4 gives components, layout and the electrical schematic of the SMA control circuit used for physical robot realization. Since there are four SMAs in the robots' body, working in pairs, the described scheme is implemented twice, once for each pair of SMAs.

EXPERIMENTAL VERIFICATION

Different versions of a worm-like soft robot have been produced and their performance results compared. Body height has proven to have a considerable influence on the robot's performance. Figure 5 gives the comparison in lift between a robot with a 6 mm tall back height and a robot with a 9 mm tall back height. The robot with a smaller back height gives a larger deformation.

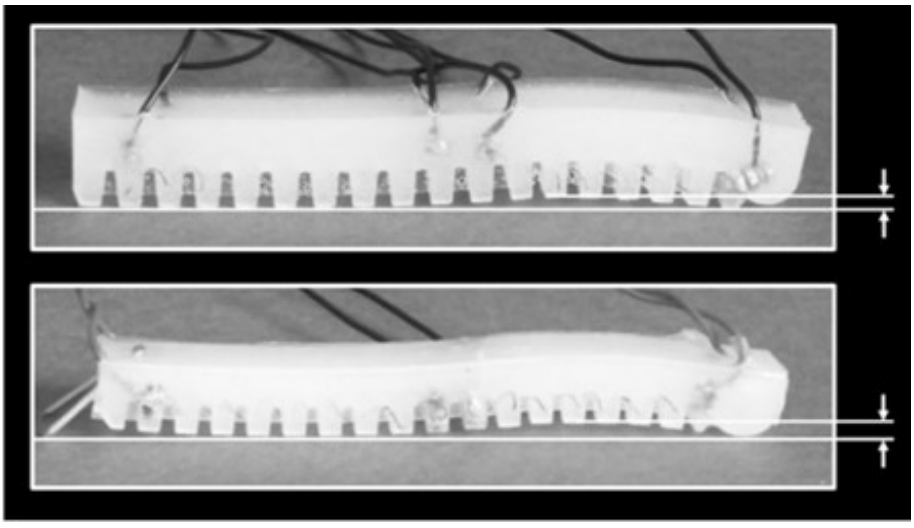


Figure 5. Comparison in achieved lift between robots with different cross sections (by height).

The difference is not only in the deformation absolute amplitude, but also in the speed of the deformation and its relation to the voltage applied. Deformation occurs faster in the robot with a smaller cross section and smaller voltage levels are required, but this is a trade off with the relaxation phase which is faster in the case of a larger cross section. This implies higher forces generated in elastic body of the robot which are used in the relaxation phase.

An experimental approach to determining the relation between increased stiffness for larger cross section and compliance for the smaller cross section is performed. Finally adopted height of the cross section is set to 6 mm.

One complete motion cycle is shown in Figure 6. At first, the rear actuators are electronically activated, lifting the rear half of the robot. This produces most of the movement, approximately 4 mm. As the rear part relaxes, simultaneously the first one is excited with electrical current and lifts. The lift of the front part of the body gives a smaller movement, usually pulling the robot 1 mm forward. At the end of one complete cycle, the robot has moved 5 mm. This depends on external factors, with surface being the most significant one.

Different surfaces were tried, with the best results achieved on soft surfaces such as linoleum, Styrofoam, and rubber. It is important to stress here that friction coefficients, and their ratios play a critical role in the forward motion cycle. In the active phase, the friction between the tail skids and the surface must be smaller than the friction between the front contact area and the surface.

This enables the back part of the body to be pulled in the desired – forward direction without simultaneous movement of the front part in the opposite direction. In the second phase, when the relaxation begins, the friction between the tail skids and the surface must be higher than the friction between the front contact part of the robot and the surface. Only this will enable a directional movement of the robot. This is a challenging design task that can be observed as a

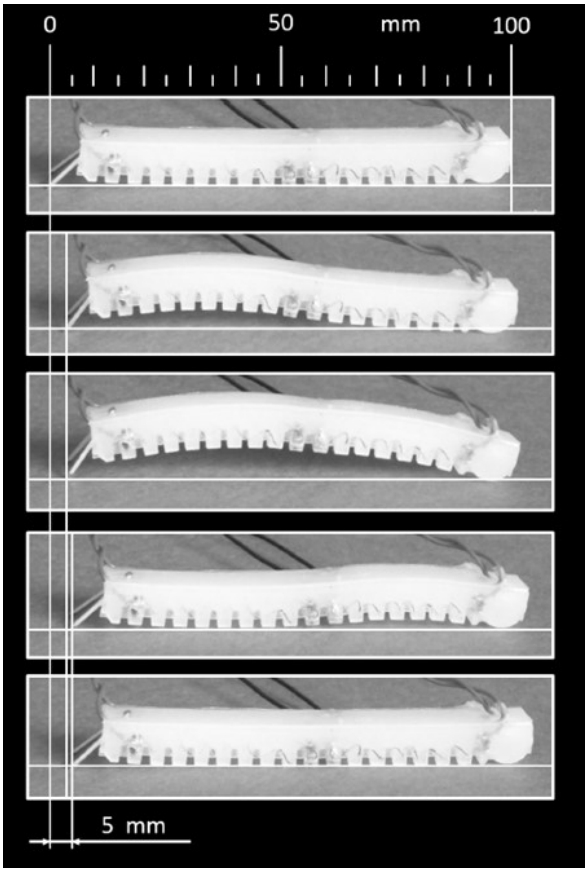


Figure 6. One complete motion cycle.

future improvement in applying directional friction surface to the contact region under the head of the robot. To break the coefficient of friction between these two phases, our approach utilizes the tail skids (to increase the back part friction) and a curved shape of the robot's head to decrease the friction of the front part in the relaxation phase.

In a step-cycle, the time, current, and voltage parameters need to be synchronized. The robot was tested at a voltage of 9 V, with the paired actuators drawing slightly less than 3 A of current, which is slightly above the recommended current which is 2,2 A. The duration of applying current to the actuators is one second, while the release time is three seconds. This time is sufficient for good deformation and relaxation, allowing the robot to fully settle on the surface it occupies. This is crucial because otherwise, the tail skids do not detach from the surface, causing the robot to get stuck and move in one place. For a detailed comparison between different approaches to realization of mobile soft robots, Table 3 is given. Parameters of interest are body material, actuation type, locomotion, and softness of the robot.

Table 3. Comparison of simple soft caterpillar robot with the other referenced soft robots.

Robot	Material of body	Type of actuation	Type of motion	Softness
Ćurković and Mlivić	ALPA-SIL silicone	NiTi SMA actuators	Crawling (caterpillar)	Soft
Seok et al. [8]	Polyether ether ketone (PEEK) braided mesh tube	NiTi SMA actuators	Crawling (peristaltic)	Soft
Luo et al. [9]	Silicone rubber	Fluidic elastomer actuators (FEA)	Snake locomotion	Soft
Pfeil et al. [10]	Silicone strenghtened with textile	Dielectric elastomer actuator	Crawling	Soft
Munadi et al. [11]	Silicone rubber RTV-52	motor-tendon actuator	Crawling (via limb bending)	Semi-rigid (soft arms connected to a rigid base)
Chua and Yeow [12]	Printed polyurethane	Air propulsion	Locomotion (via limb bending)	Semi-rigid (soft limbs connected to a rigid base)
Mc Caffrey et al. [13]	Composite of rubber-like material and rigid material (similar to ABS plastic)	SMA (wirelessly powered)?	Crawling (caterpillar)	Semi-rigid
Marchese et al. [15]	Silicone	FEA	Swimming	Semi-rigid fully rigid front body connected to a soft tail)
Joshi et al. [16]	Silicone	Fluidic actuator	Swimming	Soft
Zhang et al. [17]	Silicone body	Pneumatic	Locomotion	Soft
Lin et al. [18]	3D printed elastic ribbon surrounding pneumatic artificial muscle	McKibben pneumatic actuator	Crawling	Semi-rigid
Kandahari et al. [20]	Fabric	Servomotor	Locomotion	Soft
Joyee et al. [21]	Soft polymer	Magnetic actuation	Crawling (caterpillar)	Semi-rigid (ends of robot are rigid actuators)

Nitinol springs, used in the robot presented in this study, perform their function when they reach the required temperature. In this case, it does not matter whether the voltage is higher or lower; the change occurs with temperature. Current and voltage parameters only affect the speed of reaching the austenite to martensite transition temperature. Springs with smaller diameters, like those used in this study, have sufficient resistance, and additional connection with resistors to Nitinol springs is unnecessary. When heating the springs, the only important thing is not to overheat them, which means that the time of releasing the current through the spring must be limited. If the rated voltage is increased, the time to reach the transition temperature must be reduced, as with a higher voltage, the actuators will draw more current, and heating will occur more quickly.

However, when testing at such currents and voltage, the actuators quickly fail due to overheating, even though the heating time is short, just a few hundred milliseconds.

Although the time is restricted, the springs suddenly draw currents much higher than recommended, leading to failure because the springs cannot withstand such a large flow of energy passing through them. The recommended power is 20 W, which corresponds to a voltage of 9 V and a current of 3 A, the parameters for the proper operation of the actuators in the tested robot.

For the given parameters, a step of 5 mm was achieved in one cycle. The test results were compared with the theory of walking. The figure depicts a complete cycle of the robot's movement. It begins with the deformation of the rear segment, where most of the movement for one cycle is generated. The displacement of the rear segment during deformation is even 4 mm. It is followed by the phase of transferring the body to the first segment, where the rear segment relaxes simultaneously while the front segment deforms. The first segment creates a very small movement, usually a deformation of 2 mm, pulling the entire robot forward by 1 mm. With good adherence of the tail skids to the substrate, a movement of 5 mm is achieved in one cycle, as illustrated in Figure 6.

CONCLUSIONS

In this study a complete process of designing a caterpillar-like soft robot is presented. Each phase in the process is reevaluated and compared to previously proposed designs. The focus set was the simplicity of the design, minimization of components used to generate motion and the ease of the manufacturing process of the robot.

The robot presented in the study has fewer components, materials used are readily available and more affordable comparing to those used in comparable studies. There are some limitations originating from this. In the first line, SMAs used in this study have a high activation temperature and their contraction is significantly smaller compared to the top of the market ones. However, they make up for smaller contractions and higher activation temperatures with their significantly lower price.

The SMAs which are lower on the price range have proved to be suitable for this application. They are a limiting factor in achieving a more pronounced deformation of the robots' body. This has been compensated by the design of the body to decrease the force needed to deform the upper body part, through the reduction of the robots' body height h.

The part of the robot which forms its back has a critical role, as it is used as an elastic spring which enables the relaxation and helps to bring the SMA back to the original shape after actuation. So, the balancing between the elastic constant of this flexural spring and force generated by the SMA used is required and performed experimentally.

Further analysis shall be performed based on hyperelastic material modelling of the robot's body which will enable the modelling of this parameter and its optimal selection. The next limitation which has proven critical is the heat generated by the SMA. This heat does not dissipate fast enough through the robot's body, and residual heat limits the SMA in austenite to martensite transition. The consequence is that after a small number of cycles the robot cannot generate forward motion. Designing more intense heat transfer from the silicone area in contact with SMA to the outer surface of the robot's body is the big challenge for further development of the soft robot. The silicone used in this study is also a limiting factor with ~ 35 % smaller elongation compared to silicones used in other studies. The silicone used for the robot presented in this study is perfectly safe for handling. It is also used for medical applications – dental and orthopedics, which makes the robot suitable for a broad range of research and educational purposes.

Future research will include modelling of the silicone used based on experimentally determined elastic constants of this material. This will enable the formulation of a realistic material model to be used in simulation and optimal design parameters selection for robots' body.

Additional effort will be made to model and realize more intense heat transfer from the SMA to the outer surface. A different wiring solution should also be considered, in which the wires would be routed together to the robot, in a single cable and then be moved to their connecting spot, either on the surface of the body or even through the silicone body. This can be compared to the current version, regarding possible problems with the robot's flexibility and movement or a possible impact on heat dissipation from the wires leading to the SMAs. In addition, there is room to improve the movement of the body through implementation of directional friction. This design exploits tail skids to ensure variable friction which enables the robot to propel forward. By combining tail skids with smart materials which can generate different frictions in principal axes, a reduction in sliding of the robot in the relaxing phase can be achieved which leads to increased distance travelled in a single power cycle through this difference.

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