STRATEGIC MANAGEMENT, Vol. XX (202x), No. x, pp. 0xx-0xx

DOI: 10.5937/StraMan2500003Z

Received: November 21, 2024
Revised: February 12, 2025
Accepted: March 03, 2025
Published online: April 25, 2025

Balanced Scorecard Perspectives as a Driver for Leadership in HEIs in the Era of Industry 5.0: A SEM-ANN Approach

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Abstract

Background: It is well known that Industry 5.0 can have an impact on improving organisational performance. Higher education institutions have significant potential for social development. Besides Industry 5.0 as a new research area that can impact the improvement of organisational performance, the strategic Balanced Scorecard model can be used to enhance organisational performance. One of the most important factors with the greatest impact on organisational performance is leadership. Higher education institutions leadership must establish mechanisms for measuring and improving organisational performance.

Purpose: The aim of the paper is to analyse the impact of the perspectives of the strategic Balanced Scorecard model on the leadership variable in higher education institutions in the new era of Industry 5.0. The Balanced scorecard perspectives include financial and non-financial performance indicators.

Study design/methodology/approach: Four research hypotheses were tested in the paper through the analysis of data collected from employees at higher education institutions (primarily teaching staff, but also some administrative staff) in Serbia and the region. A questionnaire was used in the research to analyse the attitudes of employees on a five-point Likert scale. The instrument was applied to a sample of 374 correctly completed responses, using Structural Equation Modelling and Artificial Neural Networks.

Findings/conclusions: The study examines the impact of BSC variables (financial perspective, learning and growth perspective, internal business processes perspective, and customer and stakeholder perspective) on leadership. The results show that all four observed BSC variables have a positive impact on leadership, thus confirming all the examined hypotheses. Such conclusions indicate that performance achievements can significantly direct and shape leadership in HEIs in the new era of Industry 5.0.

Limitations/future research: The most significant limitation of this paper relates to the lack of research on quality models in organizations in general, and especially in higher education institutions, particularly considering that Industry 5.0 is a new research area. Furthermore, the research can be expanded to other areas. Expanding the research to other service or production sectors could provide a more comprehensive equation analysis. Additionally, recommendations for future research may include exploring additional predictors and expanding the research to other countries to enable mutual comparison of research findings.

Keywords

Balanced scorecard (BSC), higher education institutions (HEIs), Industry 5.0, leadership, quality

Introduction

Sustainable quality in higher education is a growing research area within academic circles (Bao et al., 2024). Higher education institutions (HEIs) are fundamental to overall societal development and significantly influence a country's economic growth (Bing, 2023; Dyer & Dyer, 2017). Thus, investing in higher education has positive effects on both economic and social development (Bing, 2023; Dyer & Dyer, 2017). Therefore, establishing well-designed strategies for sustainable quality is crucial for HEIs (Bao et al., 2024). However, the sustainable development of HEIs requires strategies that can contribute to a knowledge society, fostering openness to innovation and global challenges (Laura Icela et al., 2023). Enhancing quality poses a challenge for all HEIs, conditioning them to strive at implementing quality models for sustainable institutional development (Singh & Jasial, 2021).

On the other hand, today's sustainable development demands pronounced agility from any organisation to adapt quickly to rapid changes (Erceg & Zoranović, 2022). Accordingly, leaders face challenges in seeking strategic management tools to sustain HEIs and enhance performance (Kiriri, 2022; Nazari-Shirkouhi et al., 2020). Consequently, the modern world imposes high demands and new challenges on leadership and strategic management to monitor and adapt to rapid technological changes, necessitating the application of sophisticated models to improve performance and enhance the quality of higher education services in a global environment (Serdar Asan & Tanyaş, 2007). The knowledge society requires new values and competencies, particularly for teaching staff and students, preparing them for the new era of Industry 5.0 (Lamine et al., 2021). However, modern technologies and tools alone are not sufficient for technological advancement, but agility of HEIs is necessary along with continuous enhancement of skills, knowledge, and competencies among students and especially among teaching staff (Lennox et al., 2021). Such an inevitable need for collaboration between new technologies and humans is the core aspect of the current industrial era, called Industry 5.0.

However, there is very little knowledge about the application of Industry 5.0 as a relatively new research area in higher education (Hashim et al., 2024). Additionally, there is a lack of literature on the prevalence of digital technologies in higher education as a proportional relationship to economic development, considering that digital technologies in higher education significantly influence a country's development (Bing, 2023).
There is a lack of literature on influence of organisational performances on leadership (Ukko et al., 2007). Within it, there are only a few studies that have explored the impact of BSC performances on leadership.
It is particularly interesting that emphasis has been placed on the lack of research regarding the impact of financial performance on leadership (Qu et al., 2024). However, some authors, such as Van Thuong and Singh (2023), suggest that the impact of the BSC on different management levels should be further investigated. On the other hand, the impact of Industry 5.0 is particularly significant today, yet as a new research area, but insufficiently represented in the literature (Hashim et al., 2024). Accordingly, a foundation has been established for the development of a conceptual model and hypotheses that examine the impact of BSC perspectives on academic leadership in the new era of Industry 5.0.

As a result, this paper aims to examine the impact of Balanced Scorecard (BSC) performance perspectives on leadership in the Industry 5.0 era within higher education. The contribution of this research is to fill the gap in the literature related to the analysis of the impact of BSC perspectives on leadership in HEIs in the new era of Industry 5.0.

1. Theoretical background

1.1. Literature review

A well-established quality management system (QMS) plays a key role in achieving sustained quality (Glogovac et al., 2022), given the new industrial trends quality gaining increasing importance (Monteiro et al., 2021; Overberg et al., 2019). Ensuring quality in higher education represents a strategic direction for HEIs (Makki et al., 2023; Kiriri, 2022; Sánchez-Chaparro et al., 2020; Stejskal et al., 2020; Nazari-Shirkouhi et al., 2020). Considering that HEIs are the foundation of societal development and that the field of higher education plays an essential role in training future drivers of economic activity (Almuhaideb & Saeed, 2020), assessing the level of quality in higher education can be done from the perspective of stakeholders in HEIs (Bairagya & Joy, 2022). Despite existing research on quality in higher education, the dynamic nature of higher education

requires continuous and systematic analyses using sophisticated models to improve the quality of higher education institutions (Almuhaideb & Saeed, 2020). Accordingly, ensuring the quality of HEIs in the new era of digitalization and globalization is a complex process (Feng, 2023). The future of higher education is based on a digital foundation (Aytar & Arslan, 2024). In line with this, Industry 5.0 requires new strategies to improve multidisciplinary education for the future (Broo et al., 2022). Industry 5.0 requires the integration of digital technologies and people, which can impact the improvement of organisational performance (Barata & Kayser, 2024). As a new research area, Industry 5.0 aims to centre people in higher education through enhanced human-machine collaboration as a new concept for improving organisational performance (Hashim et al., 2024; Carayannis & Morawska-Jancelewicz, 2022).

A strategic tool that can be used to enhance organisational performance in HEIs is the application of the (BSC) model, based on four perspectives: Financial Perspective, Internal Business Processes Perspective, Learning and Growth Perspective, and Customer Perspective (Kiriri, 2022; Al Jardali et al., 2021; Stejskal et al., 2020; Nazari-Shirkouhi et al., 2020; Lin et al., 2016; Serdar Asan & Tanyaş, 2007). There is a positive relationship between the implementation of Quality Management Systems (QMS) and the improvement of organisational performance (Sfreddo et al., 2021). One of well known, internationally applied models, ISO 9004, provides guidelines for achieving sustainability that can significantly improve organisational performance and create a solid foundation for sustainable development (Glogovac et al., 2022; Bravi & Murmura, 2022).

In line with this, the (BSC) model can be used, incorporating both financial and non-financial indicators for measuring and enhancing organisational performance to improve or establish a strong foundation for sustainability (Makki et al., 2023; Kiriri, 2022; Al Jardali et al., 2021; Kaplan & Norton, 1992). The BSC as a tool for improving organisational performance, can assist managerial structures in HEIs in making business decisions efficiently and effectively (Camilleri, 2021). Sustainability in HEIs is an area of particular interest given the competition at the global level, and therefore, senior management in HEIs can conduct a multidimensional analysis using the BSC model by developing a strategic map to enhance organisational performance (Kiriri, 2022; Stejskal et al., 2020). The BSC model for improving organisational performance can be applied in all organisations in the public sectors, and it is also applied in HEIs (Camilleri, 2021; Kaplan & Norton, 1996). Formulating and redesigning the educational strategy by higher education policymakers and leadership establishes a solid foundation for creating a path to sustainability, in which universities play a crucial role (Hashim et al., 2024). Leadership is considered a key factor for developing a sustainable path (Glogovac et al., 2023). On the organisational strategic map, leadership is crucial for translating strategy into operational goal achievement (Kaplan, 2009). Effective leadership influences the efficiency and effectiveness of organisations (Ballester-Miquel et al., 2017). Leadership and leader commitment are vital for driving initiatives and further steps in implementing strategic models for performance improvement (Rhodes et al., 2008). To achieve sustainability in HEIs and obtain the best results, leadership must establish mechanisms for measuring and monitoring organisational performance to improve quality (Kiriri, 2022). The performance improvement models fail in organisations due to a lack of leadership commitment, which is the most significant variable affecting the success or failure of model implementation (Kaplan, 2009). Improving quality and creating an effective management system should be an ongoing goal for the leadership of HEIs (Borishade et al., 2021).

1.2. Hypothesis development

Performance measurement should be considered from multiple perspectives, including the impact of performance measurement on leadership (Lucianetti et al., 2019; Ukko et al., 2007). Although the influence of leadership on financial performances is broadly confirmed, there are also some studies that have explored the impact of the financial perspective on leadership (Qu et al., 2024; Etse et al., 2024). The assumption is that many leadership measures could also be dependent on financial performances that can influence the shaping of leadership in that way (Qu et al., 2024). Industry 5.0, that is recognized as potentially significant for managing quality and organisational performances should also be considered in such new industrial environment. Therefore, the following hypotheses are proposed:

H1. Financial Perspective has a positive impact on the Leadership of HEIs in the era of Industry 5.0.

There is a connection between learning and leadership behaviour, as prior learning influences subsequent leadership actions (Hirst et al., 2004). Learning and knowledge sharing can be the foundation for sustainability and empowerment of leadership (Faulks et al., 2021). The learning and growth perspective helps employees in creating new value (Kaplan & Norton, 1996). Organisational performance is improved by learning and growth, so leadership needs to adopt this concept (Van Thuong & Singh, 2023). Additionally, organisational training influences the perception as well as the competencies of leadership (Lausmann & Doolen, 2024). Values, such as knowledge, change and shape the steps and actions of leadership (Hallinger & Heck, 2011).

Therefore, the following hypothesis is proposed:

H2. Perspective learning and growth has a positive impact on the leadership of HEIs in the era of Industry 5.0.

Academic leadership does not directly impact student learning; on the contrary, student success influences leadership through the teaching process, which means that academic leadership not only influences but is also affected by all processes at the higher education level (Hallinger, 2011). Academic structure and processes influence leadership (Hallinger & Heck, 2011). Enhancing teaching activities can help HEIs achieve one of the their strategic goals, which is to increase competitive advantage and create value for customers – students (Serdar Asan & Tanyaş, 2007).

Therefore, the following hypothesis is proposed:

H3. Perspective of internal business processes has a positive impact on the Leadership of HEIs in the era of Industry 5.0.

Previous studies have mostly focused on the impact of leadership on academic contexts. However, in recent years, studies have emerged that emphasize the influence of the academic context on leadership, with a particular focus on people (Hallinger, 2011). There is a connection between measuring employee performance and improving the positive effects on leadership (Ukko et al., 2007). The reciprocal relationship between leadership and customers involves monitoring the improvements or deterioration in performance, which informs future leadership actions aimed at enhancing performance (Hallinger, 2011). Customer and stakeholder satisfaction is positively correlated with leadership and leadership commitment (Negron, 2020).

Therefore, the following hypothesis is proposed:

H4. Perspective of customers and stakeholders has a positive impact of leadership of HEIs in the era of Industry 5.0.

In line with the above, a conceptual model has been developed to explore the impact of BSC perspectives on the leadership variable of HEIs in the era of Industry 5.0 (Figure 1).

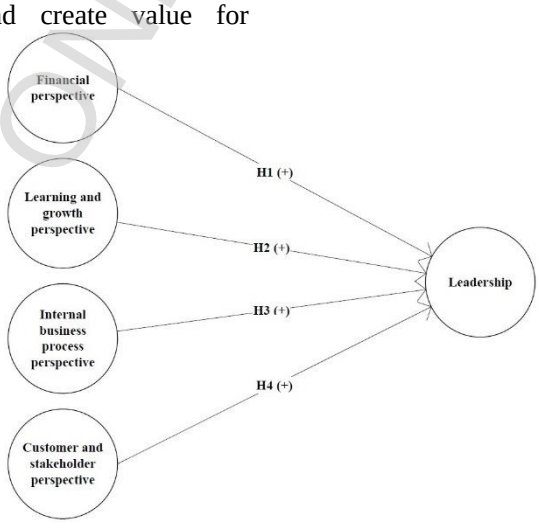

Figure 1 Conceptual model
Source: the authors

2. Methods

Although the BSC model provides a solid framework and defined measures for improving organisational performance, it lacks a detailed methodological description, mechanisms, and guidelines for selecting performance measures (Hudson et al., 2001). The model's structure (four perspectives) has been preserved in this context, but the variables have been adapted to the latest literature, thereby surpassing the initial BSC model. On the other hand, the BSC model can be successfully applied alongside quality management, yet there is a lack of literature covering these areas (Pimentel & Major, 2014). In this way, in the service sector, the customer perspective is placed in the context of all stakeholders (Stejskal et al., 2020). The research paper presents an analysis of the impact of the BSC perspectives on the variable Leadership in the era of Industry 5.0. The analysis is based on the opinions of employees in higher education institutions (HEIs).

Based on a detailed literature review, relevant literature was selected for choosing the variables for developing the questionnaire (Makki et al., 2023; Kaur, 2022; Kiriri, 2022; Al-Bahi et al., 2021; Nazari-Shirkouhi et al., 2020; Stejskal et al., 2020). The BSC variables were chosen based on the aforementioned relevant literature, while the variables for Leadership were selected based on ISO 9004:2018 (ISO, 2018). An analysis and synthesis were conducted to select the BSC variables. For the development of the questionnaire, the measurement scale from the ISO 9004:2018 was used for the leadership variables, while the measurement scale for the BSC variables was adapted based on the previous description.

The research was conducted in Serbia and its region. The countries from the region covered by the research are: Bosnia and Herzegovina, Montenegro, Croatia, and Slovenia. The research focused on employees in higher education institutions, specifically teaching staff, but also some administrative staff (student services, teaching support services). A total of 374 correctly completed responses were collected. A questionnaire was used with a five-point Likert scale. The questionnaire consists of two groups of questions, demographic and professional issues.

To achieve the study's objective, an integrated SEM-ANN approach was applied for data analysis. Structural Equation Modelling (SEM) was utilized to assess the impact of the BSC perspectives on leadership, while Artificial Neural Networks (ANN) were applied to predict this impact. Given that the SEM methodology only considers linear relationships between variables, while ANN is used for modelling both linear and non-linear connections, integrating these two techniques is beneficial. Additionally, SEM methodology tests hypotheses, which ANN cannot do. Therefore, it is significant to integrate these two techniques to analyse confirmed statistically significant factors (Akour et al., 2022; Yakubu et al., 2020; Zabukovšek et al., 2019; Sharma et al., 2017; Leong et al., 2015; Chong, 2013). For data processing, statistical software SPSS v.27.0 and AMOS v.22.0 were used.

3. Results and Discussion

The first group of questions pertains to the demographic information of the respondents. The gender distribution was 47.36% male and 52.94% female. Regarding their positions in the higher education institution, 16.84% were administrative staff, 16.84% were teaching assistants, and 66.31% were professors. In terms of academic disciplines, 7.40% were from natural sciences and mathematics, 32.15% from technical and technological sciences, 52.09% from social sciences and humanities, 6.75% from medical sciences, and 1.61% from the arts.

Analysing the age structure of the respondents, 7.75% were up to 30 years old, 25.13% were between 31-40 years old, 33.16% were between 41-50 years old, 23.53% were between 51-60 years old, and 10.43% were over 60 years old. In terms of work experience, 1.87% had less than one year of experience, 27.54% had 1-10 years, 38.24% had 11-20 years, and 32.35% had more than 20 years of experience.

Regarding the implementation of ISO 9001 and/or QMS standards, 5.61% indicated that their HEI implemented the standard more than three years ago, 23.80% said it was implemented 3-6 years ago, 46.26% reported implementation more than six years ago, and 24.33% indicated that their HEI had not implemented ISO 9001. As for the type of institution, 90.64% were public HEIs, while 9.36% were private HEIs.

The second group of questions pertains to the perspectives of the BSC, which include the Financial Perspective, the Internal Business Processes Perspective, the Learning and Growth Perspective, and the Customer and Stakeholder

Perspective, as well as a group of questions related to Leadership. The data collection period lasted from November 2023 to April 2024.

3.1. Structural Equation Modelling (SEM)

The SEM methodology enables the analysis of complex relationships between independent and dependent latent variables, as well as between latent and manifest variables (Fornell & Larcker, 1981). This methodology is used to validate models through two key steps. The first step involves specifying the measurement model, where the assumed relationships are defined and evaluated. Following this, the model is prepared for empirical testing, which allows for the verification of its validity and reliability. The second step involves defining the structural model, which facilitates the testing of proposed hypotheses (Hair et al., 1998).

3.1.1. Measurement Model

When evaluating a measurement instrument, one of the key indicators is reliability, which refers to the instrument's ability to consistently measure the phenomenon under observation. To assess internal consistency, indicators such as Cronbach's Alpha coefficient (Cronbach, 1951), Composite Reliability (CR) (Bacon et al., 1995), Spearman-Brown coefficient (de Vet et al., 2017), and the Omega test (Green et al., 2016) were applied. The recommended values for all these indicators are above 0.7 (Nunnally, 1978).

Table 1 shows the values of all reliability coefficients, confirming internal consistency for each construct.

Convergent validity was used to assess the validity of the measurement scale. Convergent validity is checked using the Average Variance Extracted (AVE) coefficient, which should be ≥ 0.5 (Fornell & Larcker, 1981). All AVE values are above the recommended threshold, confirming the convergent validity of the measurement model.

To test the relationships among latent variables, correlation analysis was used, where values greater than ± 0.3 are considered appropriate and indicate the presence of a correlation among the observed variables (Hair et al., 2014).

The results of the correlation analysis are shown in Table 2, demonstrating that all relationships were confirmed.

The next step is to assess discriminant validity, which is quantified by comparing the square roots of the average variance extracted (AVE) (Hair et al., 2014).

Discriminant validity is typically quantified by examining the correlation matrix of latent variables. The correlations between these latent variables should not exceed predefined levels. Therefore, the square root of the AVE must be greater than the correlations between factors (Hoyle, 2012), as shown in Table 2.

Fit indices are most commonly used to measure the model's fit in the Confirmatory Factor Analysis (CFA) model.

Fit indices show the extent to which the model fits the research data. These statistical indicators complement each other. The results obtained in this study indicate a good model fit, which is satisfactory, as shown in Table 3.

Table 1 Measurement model data (CFA)

Constructs	Standardized factor loadings	t-values	AVE	Cronbach Alfa	CR	Spearman-Brown	Ω
FP_1	0.782		0.657	0.937	0.938	0.918	0.938
FP_2	0.613	12.440					
FP_3	0.801	17.227					
FP_4	0.829	18.012					
FP_5	0.819	17.727					
FP_6	0.899	20.095					
FP_7	0.872	19.285					
FP_8	0.838	18.279					
LGP_1	0.869		0.710	0.972	0.971	0.946	0.972
LGP_2	0.864	23.460					
LGP_3	0.858	23.099					
LGP_4	0.832	21.792					
LGP_5	0.774	19.183					
LGP_6	0.850	22.696					
LGP_7	0.782	19.492					
LGP_8	0.828	21.583					
LGP_9	0.854	22.904					
LGP_10	0.894	25.143					

LGP_11	0.838	22.067					
LGP_12	0.808	20.640					
LGP_13	0.864	23.420					
LGP_14	0.880	24.314					
IBPP_1	0.845						
IBPP_2	0.810	19.882					
IBPP_3	0.751	17.660					
IBPP_4	0.843	21.283					
IBPP_5	0.884	23.203					
IBPP_6	0.855	21.806					
IBPP_7	0.857	21.910					
IBPP_8	0.865	22.281	0.698	0.973	0.935	0.955	0.973
IBPP_9	0.708	16.214					
IBPP_10	0.883	23.146					
IBPP_11	0.911	24.592					
IBPP_12	0.898	23.909					
IBPP_13	0.829	20.703					
IBPP_14	0.767	18.245					
IBPP_15	0.773	18.464					
IBPP_16	0.858	21.952					
CSP_1	0.860						
CSP_2	0.859	22.658					
CSP_3	0.864	22.911					
CSP_4	0.864	22.909					
CSP_5	0.839	21.696					
CSP_6	0.805	20.167					
CSP_7	0.857	22.580	0.672	0.971	0.971	0.951	0.970
CSP_8	0.863	22.873					
CSP_9	0.865	22.998					
CSP_10	0.888	24.187					
CSP_11	0.877	23.598					
CSP_12	0.842	21.830					
L_1	0.873						
L_2	0.915	26.261					
L_3	0.919	26.499	0.812	0.945	0.945	0.948	0.946
L_4	0.898	25.183					

Source: the authors

Table 2 Correlation matrix and Discriminant validity

Constructs	FP	LGP	IBPP	CSP	L
FP	**0.810**				
LGP	0.867	**0.843**			
IBPP	0.815	0.934	**0.835**		
CSP	0.810	0.898	0.933	**0.901**	
L	0.815	0.840	0.822	0.817	1

Source: the authors

Table 3 Correlation matrix and Discriminant validity

χ^2	χ^2/df	RMSEA	CFI	IFI	TLI
χ^2=3430.195; df=1367 (p<0.05)	2.509	0.064	0.915	0.915	0.911
Accepted fit	<3	<0.080	>0.900	>0.900	>0.900

Source: the authors

3.1.2. Structural Model

After evaluating the measurement model, the next step is to assess the structural model, which tests the proposed relationships between latent constructs. First, the fit indices of the structural model were evaluated. The fit indices for the defined relationships between latent variables are satisfactory. The obtained values of fit indices include Comparative Fit Index (CFI = 0.915), Incremental Fit Index (IFI = 0.911), Tucker-Lewis Index (TLI = 0.915), and Root Mean Square Error of Approximation (RMSEA = 0.064). The recommended values for CFI, IFI, and TLI are >0.90, while the recommended threshold for RMSEA is <0.08 (Hu & Bentler, 1995), confirming a good fit of the structural model.

Structural Equation Modelling tests the assumptions regarding the direction and significance of relationships between the observed

variables (Hair et al., 2014). After confirming a well-fitted structural model, the proposed relationships between latent constructs are tested. Table 4 and Figure 2 present the results of the beta coefficients and t-values of all proposed relationships. These values indicate a positive direction for all proposed relationships. However, while two hypotheses are confirmed due to statistical significance, two hypotheses, despite the positive direction, cannot be accepted due to a lack of statistical significance.

Table 4 Path coefficients

The relationship or path	Beta coefficients (β)	T-value	Causal relations
H1: Financial Perspective - Leadership	0.343	4.306	R1: yes
H2: Perspective of Learning and Growth – Leadership	0.267	1.584	/
H3: Perspective of Internal Process – Leadership	0.073	3.849	/
H4: Perspective of Customer and Stakeholder – Leadership	0.248	2.055	R1: yes

Source: the authors

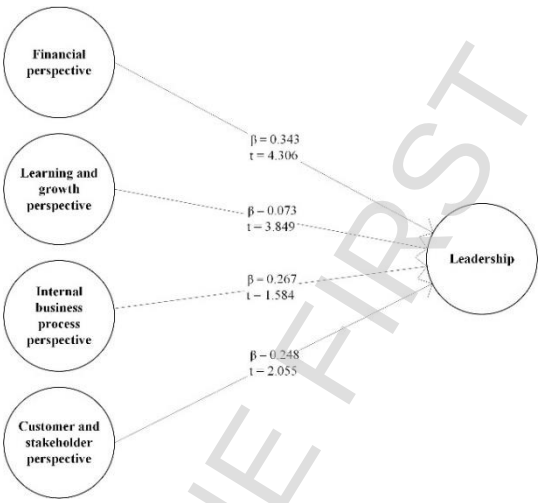

Figure 2 Path diagram model
Source: the authors

Table 5 presents the standardized factor loadings and their corresponding levels of significance, indicated by t-values, which are in accordance with the recommended values by Hair et al. (2014). Additionally, an effective analysis of the structural model results requires considering the coefficient of determination (R^2) for each structural equation in the structural model (Hair et al., 2014). Table 5 shows the coefficient of determination (R^2) for the dependent latent variable, which indicates that the percentage of explained variance for the dependent variable, Leadership, is 80%.

Table 5 Path coefficients and t-values between observed and latent variables

Variables	n	Standardized factor loading	Critical ratio or (t-value)	R^2
FP	8	0.613-0.899	12.440-20.095	/
LGP	14	0.774-0.893	19.183-25.143	/
IBPP	16	0.708-0.898	17.660-24.592	/
CSP	12	0.805-0.887	20.167-24.187	/
L	4	0.873-0.919	25.183-26.499	0.800

Source: the authors

3.1.3. Artificial Neural Networks (ANN)

To form a prediction model and determine the significance of each individual input variable, an analysis of Artificial Neural Networks (ANN) was conducted. ANN modelling was performed using statistically significant variables from the SEM methodology. ANNs have the ability to perform deep learning and enable the analysis of non-linear data (Haldorai et al., 2020). The ANN used in this study consists of three layers of neurons: the input layer (i), the hidden layer (j), and the output layer (k), with multiple neurons in each layer (Zabukovšek et al., 2019). The number of neurons (i) in the ANN input layer is equal to the number of independent exogenous variables in the SEM

methodology, while the number of output neurons (k) is equal to the number of dependent endogenous variables. However, the number of hidden neurons (j) is an adjustable parameter that depends on the desired approximation and the model's ability to generalize (Negnevitsky, 2011; Xu et al., 2019).

In this study, the ANN modelling was performed using the SPSS software package version 27. The modelling aimed to predict leadership, which is the dependent variable or output layer, while the input layer variables included the four BSC perspectives: Financial Perspective, Learning and Growth Perspective, Internal Business Processes Perspective, and Customer and Stakeholder Perspective. The ANN used in this study includes two phases: the training phase, which uses 70 to 80% of randomly selected data from the dataset, and the testing phase, which uses the remaining 20 to 30% of the data to test the network (Figure 3).

The model in this study predicts leadership, which is used as the output layer in the neural network, as shown in Figure 4. The input layer in the neural network utilized four predictors from the SEM methodology, which are the four BSC perspectives. The network produced five neurons in the hidden layer. Following the research of Ruso et al. (2024), Asadi et al. (2019), Chan and Chong (2012) where ten iterations for the cross-validation procedure were proposed with 70% of the data used for training and 30% for testing, this study also conducted ten iterations, as seen in Table 6 and Figure 3.

The Root Mean Square Error (RMSE) was calculated to assess the accuracy of the proposed model, by evaluating the data sets in both the training and testing phases. As shown in Table 6 and Figure 3, the RMSE in the training phase is 0.358, while in the testing phase it is 0.364. Based on the obtained low RMSE values, it can be concluded that the ANN model indicates accurate data relationships between the input predictor variables and the output variable.

Table 6 ANN Model Results

	Training 69.3% (n = 260)			Testing 30.7% (n = 114)		
ANN	**N**	**SSE**	**RMSE**	**N**	**SSE**	**RMSE**
ANN1	255	33.896	0.365	119	12.973	0.330
ANN2	254	33.276	0.362	120	13.331	0.333
ANN3	254	34.934	0.371	120	15.268	0.357
ANN4	271	35.491	0.362	103	12.960	0.355
ANN5	255	25.909	0.319	119	22.742	0.437
ANN6	262	32.202	0.351	112	14.928	0.365
ANN7	263	35.387	0.367	111	17.433	0.396
ANN8	271	34.792	0.358	103	12.780	0.352
ANN9	260	34.181	0.363	114	16.951	0.386
ANN10	271	36.445	0.367	103	10.798	0.324
Average			0.358			0.364

Source: the authors

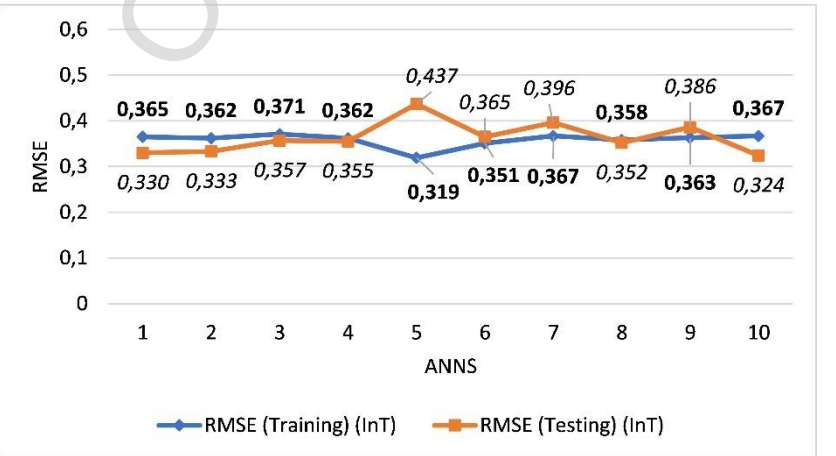

Figure 3 RMSE Performance
Source: the authors

Figure 4 illustrates the ANN model which predicts and evaluates the strength of the impact of the four BSC perspectives: Financial Perspective, Learning and Growth Perspective, Internal Business Processes Perspective, and Customer and Stakeholder Perspective on the variable Leadership.

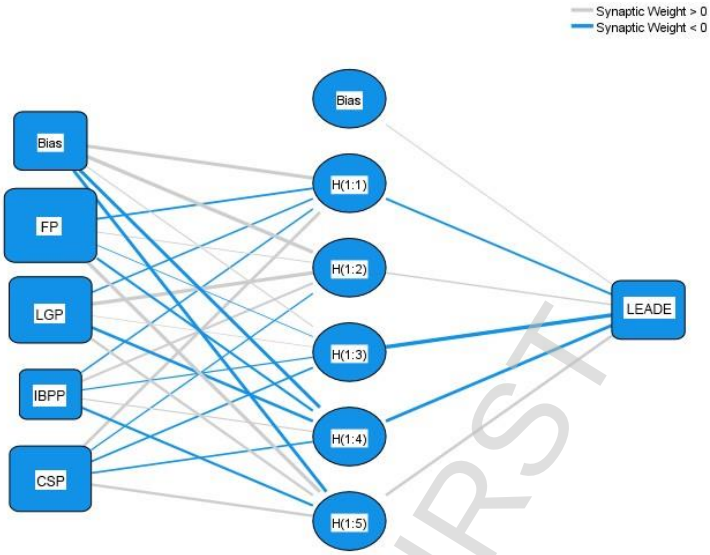

Figure 4 Artificial Neural Network
Source: the authors

To determine the relative impact of each observed factor, sensitivity analysis can be utilised (Chong, 2013). Sensitivity analysis is used to calculate each construct as a proportion of relative importance with the highest relative importance (Sharma et al., 2016).

In this study, sensitivity analysis was obtained based on the average importance of independent variables (Financial Perspective, Learning and Growth Perspective, Internal Business Processes Perspective, and Customer and Stakeholder Perspective) to evaluate the prediction of the dependent variable (Leadership). Based on the results in Table 7, it is observed that the Financial Perspective dimension has the greatest significance, while the Internal Business Processes Perspective has the least significance. Sensitivity analysis is quantified by the importance of independent variables for the prediction of dependent variables (Chong, 2013).

Table 7 Significance of Independent Variables

Predictors	Significance	Normalized Significance
Financial Perspective	0.372	100.0%
Learning and Growth Perspective	0.278	74.9%
Customer and Stakeholder Perspective	0.269	72.7%
Internal Business Process Perspective	0.081	21.7%

Source: the authors

The final step of the conducted methodology is the comparison of influential predictors on Leadership, presented in Table 8 based on the SEM methodology and artificial neural networks (ANN). In Table 8, approximately the same values and the same ranking of the significance of individual perspectives on Leadership are observed. Based on the results obtained from the SEM-ANN methodology, it can be concluded that the Financial Perspective has the strongest impact on Leadership, followed by the Learning and Growth Perspective, then the Customer and Stakeholder Perspective, and the predictor with the least significance is the Internal Business Processes Perspective.

Table 8 Comparison of SEM and ANN

Predictors	ANN	SEM
Financial Perspective	37.2%	34.3%
Learning and Growth Perspective	27.8%	26.7%
Customer and Stakeholder Perspective	26.9%	24.8%
Internal Business Process Perspective	8.1%	7.3%

Source: the authors

In this research, an integrated SEM-ANN methodology was used to determine the impact and prediction of perspectives from the BSC matrix on Leadership in the Industry 5.0 era. Based on the SEM methodology, hypothesis testing was conducted, where all hypotheses have a positive impact. However, two hypotheses were confirmed,

while two were rejected, showing a positive impact but lacking statistical significance. Within the research hypotheses, the values of regression coefficients (β-path coefficients) have positive values, while the t-test values are greater than the recommended value of 1.96, which is considered appropriate for analysis as noted by Hair et al. (2014).

The research hypothesis H1, which assumes that the Financial perspective is related to Leadership, has been confirmed, consistent with the research by Etse et al. (2024). Financial performance is linked to the strategy and mission of an organisation, and if the desired financial result is not achieved, leadership should establish mechanisms for reviewing and achieving the goals of the strategy and mission, as not all strategies, particularly long-term ones, are simultaneously profitable (Kaplan & Norton, 1992). The results obtained in this study are (β=0.343; t=4.306; $p<0.001$), which shows that hypothesis H1 is accepted. The obtained results can be compared based on the SEM and ANN approaches. According to the ANN analysis, the financial perspective occupies the leading first place on the hierarchical scale. One of the challenges for leaders of HEIs is financial sustainability (Makki et al., 2023; Kiriri, 2022; Al-Bahi et al., 2021; Stejskal et al., 2020; Nazari-Shirkouhi et al., 2020).

Hypothesis H2, which relates to the presumed positive impact of the learning and growth perspective, despite its positive direction, does not have statistical significance and therefore cannot be accepted (β=0.073; t=3.849; $p<0.001$). An environment that encourages constant learning for both leadership and other employees, is a permanent goal of leadership (Yang & Islam, 2012; Amey, 2005). Management mechanisms of organisational performance are linked to improvement, learning, and innovation (Glogovac et al., 2023). Additionally, the ANN approach shows that the learning and growth perspective is the second significant predictor of leadership. The connection between learning and growth and leadership was found in the study by Brown and Posner (2001), where the authors identify the link between how leaders learn and how it can influence their future actions. They also suggest that learning tactics, such as sensing and approaching others, can best assist in developing their leadership abilities.

The research hypothesis H3 concerns the impact of the internal business process perspective on leadership (β=0.267; t=1.584; $p<0.001$), which also has a positive impact, but due to the lack of statistical significance, this hypothesis cannot be accepted. The results of the ANN analysis indicate that the internal business process perspective ranks third in terms of significance for leadership, which is consistent with the results of the SEM method. Translating long-term goals into operational organisational objectives should be a constant aim of leadership, considering that internal business processes correlate with customer satisfaction (Kaplan & Norton, 1996). Organisations must excel in their operational activities to improve overall operational performance (Nazari-Shirkouhi et al., 2020). However, according to McElheran (2015) operational activities will not impact leaders in adopting various innovations in their process, regardless of their internal adaptation costs. Additionally, the higher education system has a specific nature, making it challenging to manage internal processes (Vykydal et al., 2020). These findings support the results obtained in this study.

Hypothesis H4 assumes the impact of the customer and stakeholder perspective on leadership (β=0.248; t=2.055; $p<0.001$), which confirms this hypothesis. Customer satisfaction implies that a customer is happy enough to recommend the company's product to their environment and community, influencing the company's leadership with their specific demands (McElheran, 2015). In higher education, for customers to be satisfied, leaders of HEIs must establish mechanisms for short-term and long-term strategies that will fully meet the expectations of students as customers and all other stakeholders (Camilleri, 2021). Based on the comparison of SEM and ANN analysis, approximately similar values are observed for the impact of the customer and stakeholder perspective on leadership. This research contributes to the knowledge on using an strategic BSC model and serves as a proposed framework for HEIs leadership in the new era of Industry 5.0.

Conclusions

Industry 5.0, as a new research area in the global era, brings numerous challenges to HEIs in changing the way educational services are provided and raises many questions about how best to leverage the advantages of digital technologies and the changes brought by the new era of Industry 5.0, which is not yet well-researched in higher education (Hashim et al., 2024). Although the influence of leadership on organisational performances is broadly researched, there are some

indications that leadership could be dependent on some performances as well. It is concluded that performance measurement shapes academic leadership in the new era of Industry 5.0. Furthermore, it is concluded that academic leadership must continuously invest efforts to achieve and maintain the sustainability of HEIs for the future environment of Industry 5.0. For higher education institutions to achieve a competitive advantage in the global era, leadership must continuously strive to improve all related organisational performances. To achieve financial sustainability, additional value must be created for customers (Kaplan & Norton, 1996). Moreover, HEIs must excel in operational activities while creating mechanisms for continuous learning for employees (Nazari-Shirkouhi et al., 2020). Based on this, previous studies have focused on the application of the BSC model in higher education (Kiriri, 2022; Al-Bahi et al., 2021; Stejskal et al., 2020; Nazari-Shirkouhi et al., 2020), while the application of Industry 5.0 in higher education is extremely rare (Hashim et al., 2024), which is understandable as it is a new research area.

On the other hand, leadership is considered a key variable for business outcomes (Kaplan & Norton, 1992). Consequently, this study makes a step forward and aims to investigate the impact of the BSC perspectives (Financial Perspective, Learning and Growth Perspective, Internal Business Processes Perspective, and Customer and Stakeholder Perspective) on the variable Leadership in higher education institutions in the era of Industry 5.0. Given that the top management of higher education institutions must continuously invest intensive efforts in developing a roadmap towards sustainability, HEIs face challenges such as reduced public funding, an increase in the establishment of private higher education institutions, and heightened expectations from all HEI's stakeholders, presenting multiple challenges for leadership (Kiriri, 2022). From this perspective, the practical contribution can be seen in the advantages and opportunities that the managerial structures of higher education institutions can utilize to improve performance. This research contributes to the knowledge on using an strategic BSC model and serves as a proposed framework for HEIs leadership in the new era of Industry 5.0. Practical implications can be observed through shaping the future steps and actions of HEI leaders. Although the BSC model provides a solid framework and defined measures for improving organisational performance, it lacks a detailed methodological description, mechanisms, and guidelines for selecting performance measures (Hudson et al., 2001). BSC variables were used based on recent literature review. A detailed methodological insight has been highlighted for HEI leaders regarding the specific performance of the BSC model, which has been found to impact leadership. Since the study examines the perspectives of employees in HEIs, leaders can measure performance through the opinions and attitudes of students or other stakeholders. In this way, specific procedures for applying this model have been defined for HEI leadership. Given that the research was conducted at an institutional level, HEI leaders can adapt the proposed model to individual processes and needs. This model is generic and can be used by management structures of both public and private HEIs. The research findings provide insights into how leaders can shape future steps to achieve a competitive advantage for HEIs. The most significant limitation of this paper relates to the lack of research on quality models in organizations in general, and especially in higher education institutions, particularly considering that Industry 5.0 is a new research area. Also, one of the major limitations of the paper is a small amount of literature on the impact of performance measurement on leadership, although there are some indices that performance measurement should be considered from the perspectives of their impact on leadership (Lucianetti et al., 2019; Ukko et al., 2007). Additionally, Industry 5.0 is a new research field and has not been sufficiently researched, especially in the area of higher education. Industry 5.0 is a global phenomenon that encompasses the entire world. Furthermore, considering that Industry 5.0 is still in its development phase, it is expected that additional research will be conducted in the future to explore the various ways in which Industry 5.0 can transform society.

Previous studies have mostly focused on the impact of leadership on organisational performance; however, there is a very small amount of literature that has explored the reverse relationship (Lausmann & Doolen, 2024; Qu et al., 2024). Performance measurement should be viewed from different perspectives (Ukko et al., 2007). Such conclusions indicate that performance measurement significantly directs and shapes academic leadership in the new era of Industry 5.0. It is also concluded that academic leadership must continuously invest efforts to achieve and preserve

the sustainability of HEIs for the future environment of Industry 5.0. This research contributes to the limited literature on how performance measurement influences the future steps and actions of HEI leadership. The directions for future research could encompass other areas in order to provide a more comprehensive analysis. Additionally, recommendations for future research may involve exploring additional predictors. This study needs to be explored more deeply and broadly from different perspectives. Future research could also cover other countries or regions to enable mutual comparison of the results obtained, considering that Industry 5.0 is a global phenomenon but still under-researched.

Declarations

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Funding

Not applicable.

Acknowledgements

Not applicable.

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Appendix

The questionnaire items

CONSTRUCTS	VARIABLES	CODE
FINANCIAL PERSPECTIVE (FP)	Revenue from commercial research	FP_1
	Implementing a paperless process practice	FP_2
	Annual core revenue growth	FP_3
	Increasing revenue and other economic benefits from other sources	FP_4
	Reducing operational costs	FP_5
	Diversification (redistribution) of income	FP_6
	Minimization of risks	FP_7
	Balancing of budget allocations	FP_8
LEARNING AND GROWTH PERSPECTIVE (LGP)	Improvements, learning, and innovations Improvement	LGP_1 LGP-2_
	Learning	LGP-3
	Innovations	LGP-4
	Empathy	LGP-5
	Incentive and facilitation of training	LGP-6
	Managerial conduct	LGP-7
	Engagement in research projects (grants)	LGP-8
	Effects of implementing technologies in the teaching process	LGP-9
	Effects of innovations	LGP-10
	Collaboration with industry	LGP-11
	Improving international collaboration	LGP-12
	Innovativeness of scientific research	LGP-13
	Acquisition of organisational knowledge	LGP-14
INTERNAL BUSINESS PROCESSES PERSPECTIVE (IBPP)	Results of scientific research Alignment of curriculums with the labour market needs	IBPP_1 IBPP_2
	Availability of computers	IBPP_3
	Innovations in teaching delivery	IBPP_4
	Integrated use of technologies	IBPP_5
	Increase in the number of competent teachers	IBPP_6
	Student satisfaction with the teaching process	IBPP_7
	Number of domestic and international awards for teaching excellence	IBPP_8
	Online databases, scientific journals, and available library resources	IBPP_9
	Operational efficiency	IBPP_10
	Continuous improvement	IBPP_11
	Efficiency of utilizing all significant resources	IBPP_12
	Dual education	IBPP_13
	Aim towards salary/earnings equality in relation to EU countries	IBPP_14
	Organization student support activities	IBPP_15
	Educational outcomes	IBPP_16
CUSTOMER AND STAKEHOLDER PERSPECTIVE (CSP)	Employer satisfaction Satisfaction of former students	CSP_1 CSP_2
	Economic development of the local community	CSP_3
	Educational experience	CSP_4
	Increase in the number of students	CSP_5
	Implementation of Industry 5.0 has contributed to reducing study time	CSP_6
	Increase in the number of students with awards, honours..	CSP_7
	Awards, recognitions, merits..	CSP_8
	Improvement of public image and maintenance of reputation	CSP_9
	Quality of education	CSP_10
	Contribution to the country's economic development	CSP_11
	Addressing social issues and provision of benefits to students	CSP_12
LEADERSHIP (L)	Assess the leadership Establishing Policy and strategy	L_1 L_2
	Goals established	L_3
	Quality of communication	L_4

*With the aim of the described variables by categories (constructs), all variables refer to the degree of application, and /or the degree of realization of the Industry 5.0 in HEIs.