TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 69, Issue II, June, 2026

STRUCTURAL EQUATION MODELING ANALYSIS OF MANDATORY DIGITAL SYSTEMS' SUCCESS FACTORS: STUDY ON THE IMPLEMENTATION OF RO E-INVOICE

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Abstract: *This paper investigates the implementation of the electronic invoicing system in Romania. The framework designed for this study evaluates a mandatory information system using the concept of user satisfaction and adapting DeLone and McLean's information system success model to include components such as compliance and legislative changes, as well as trust in the organization. To quantify the causal relationships between variables, we used the SEM PLS method. The results reveal a significant divergence from the classical models, with user satisfaction not being influenced by quality factors.*
Key words: *structural equation modeling, e-invoice implementation, e-government maturity, information system success, user satisfaction*

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1. INTRODUCTION

E-invoicing, or electronic invoicing, is increasingly being adopted across various sectors and countries, offering numerous benefits over traditional paper-based invoice systems. Many European Union (EU) member states have introduced or are implementing structured e-invoicing systems.

The Romanian Ministry of Finance and the National Agency for Fiscal Administration launched the project "E-invoice - mandatory electronic invoicing system" in March 2020 to streamline tax and fee collection, aiming to improve VAT collection and prevent tax evasion. The national electronic invoice system RO e-Invoice (RO e-Factura) was created to provide economic operators with an electronic service for issuing and receiving invoices [1]. The electronic invoice is an electronic file, in XML (eXtensible Markup Language) format, based on the European Norm (EN) 16931, ensuring interoperability across EU member states. To use the RO e-Invoice system, economic operators must be registered in the Virtual Private Space (SPV), the online platform offered by the National Agency for Fiscal Administration (ANAF) to facilitate electronic communication between taxpayers and the tax authority [1]. There are two methods for issuing or transmitting an invoice in XML format. The first method involves integrating a personal software application with the RO e-Invoice system using a series of micro-services exposed in the form of an API (Application Programming Interface). The second method involves manual uploading, using the application provided by the Ministry of Finance.

The system was gradually implemented. First stage, on July 1, 2022, it became mandatory for B2G transactions, referring to interactions between an economic operator and contracting authorities. From January 2024, the obligation extended to the B2B segment, transactions involving the exchange of goods or products and the provision of services between two economic operators. Starting January 1, 2025, it became mandatory for the commercial relations between a company and a final consumer (B2C).

RO e-Invoice adoption involved significant investments, organizational changes, tax compliance requirements, and technological integration. It also brought new legal obligations. In the private sector, companies had

to invest in electronic invoicing software or update existing accounting programs, secure internet connection, and electronic signature tools, and train their staff. Companies with limited resources and businesses in rural areas with a low level of digitalization have encountered difficulties in complying with the new requirements. Also, public institutions had to make investments for the continuous development of the platform.

Ensuring interoperability between different national systems and software environments has also been a challenge. Although the European Standard (EN 16931) provides a technical standard, implementation approaches vary. Romania, Italy, France, and Poland have adopted centralized approval models. In this way, invoices are submitted via a government-managed platform for verification. Interoperability issues have been encountered. Other countries, such as Germany and Denmark, use decentralized or hybrid models, using networks such as PEPPOL for invoice exchange, which have fewer integration issues but require adaptations to the national process [2, 3, 4].

With this study, we aim to assess the factors that impact the implementation of RO e-Invoice. In evaluating e-government information systems, technological features are not the only measure to be used; they should be correlated with the improvement of administrative activities and citizen satisfaction. Therefore, the question that arises is: To what extent is the RO e-Invoice system perceived as successful by its users, and what are the factors that influence it?

We based this study on the Information System Success Theory, a comprehensive theory designed by DeLone and McLean (D&M). This theory states that the" success and effectiveness" of a system are influenced by the way in which the system satisfies "the needs and expectations of its users" [5]. Service quality added in the revised model aligns it with the particularities of electronic and interactive systems [6]. The model has largely been used in many business areas, for instance, m-payment, e-healthcare, and e-Government. Many studies have evaluated the entire model, confirming the mutual interrelationships among its dimensions.

Regarding service quality, one of the best-known models for its evaluation is the SERVQUAL model, and its adapted version for electronic services, ESQUAL, developed by Parasuraman, Zeithaml, and Malhotra [7].

The combination of the two models, D&M and ESQUAL, allows a holistic assessment of the information system's success, covering both technical performance and user perception and satisfaction.

2. THEORETICAL FOUNDATIONS AND HYPOTHESES DEVELOPMENT

Previous research has underlined the benefits of using e-invoices in VAT administration and collection. This system has proven to be much more productive than the classic version, as it "reduces operational costs, such as printing costs and transport fees, reduces administrative errors, and eliminates postal delays" [8, 9]. Other research has proven that by adopting advanced technologies in the fiscal administration system, the degree of compliance improves, saving companies from potential fines and penalties, and reducing tax fraud [10].

Despite its advantages, there are several obstacles to the adoption of e-invoicing. Insufficient awareness and knowledge about its implementation and resistance to change within organizations, connectivity issues due to infrastructure limitations, and issues related to trust and transparency with the government affect taxpayer compliance [11].

The analysis of the performance of e-invoicing systems at a global level has been based on a variety of established theoretical frameworks. Among the most common approaches identified in the literature are the success model proposed by DeLone & McLean, along with theories focused on adoption and behavior, such as TAM (Technology Acceptance Model) or UTAUT. Also, perspectives offered by IDT (Innovation Diffusion Theory) have been explored to understand the complexity of user interaction with these platforms. The most studied factors in determining user satisfaction, as well as net benefit, are the quality of the information provided by the system and system quality.

Information quality is determined by the precision, correctness, and completeness of the data produced by the software, as evaluated by

users. It is correlated to the system's outcome, while system quality refers to the system that processes data and generates the output. DeLone and McLean stated that system quality is defined by the system's technical features. Technical characteristics can be measured by stability, feedback time, availability, user friendliness, and effortless adaptation and integration. User satisfaction measures how well a person's impression of the product, service, or information system meets their expectations. It is the result of comparing initial expectations with actual experience. Net benefits measure the differences between the positive effects and the costs of implementing the system.

Many studies have established the following interconnected relationships in e-invoice adoption: information and system quality significantly impact user satisfaction, which further positively affects net benefits. These studies demonstrate that electronic invoice adoption creates a chain of improvements, from enhanced processing of tax invoices to increased VAT reporting efficiency [11, 12, 13, 14].

To assess service quality, the most used and well-known measurement tool is SERVQUAL and its version ESQUAL, a model designed to evaluate the quality of electronic services offered by organizations, including electronic governance, aiming to adapt the assessment of traditional service quality to the digital context.

Reliability, which is the rigor and stability of the process that provides services to users; responsiveness, the ability to produce real time user services; competence, the ability to provide users with reliable services; empathy, described as care and attention in service delivery; and tangible aspects, which represent physical facilities and equipment, are the five dimensions measurable by the SERVQUAL instrument. Academic consensus indicates that perceived service quality is connected to user satisfaction. The validity of this relationship has been tested and reconfirmed in various technological contexts, underscoring the importance of technical support in the success of any system implementation [15, 16, 17].

Public service quality is essential for efficient governance; it influences citizens' day-to-day activities and outlines their view on government efficiency. Service providers should succeed in meeting community expectations by delivering trustworthy services. Trust in an institution refers to the users' perception of its capability, principles, transparency, and ability to complete its commitments. A 2021 study conducted by Chinese municipalities on factors influencing the use of electronic public services shows that "trust in government, trust in the internet, service quality, and information quality have positive effects on citizens' trust in e-government" [18].

Acknowledging how organizations respond to regulatory changes requires a review of their actions over a considerable period. It takes time for changes to be fully incorporated into an organization's systems. The adjustments that organizations are required to make to comply with new regulations, strategies, or policies imposed by authorities may involve reviewing workflows, updating information systems, and implementing new security or data protection measures. Recent studies on the impact of regulatory change, law enforcement effectiveness, and bureaucratic accountability on the quality of public service show that an increase in each factor is associated with a higher quality of public service [19]. Other studies have shown that high-quality digital services produce public value defined as increasing conveniences, flexibilities, and process simplification for citizens [20].

Few studies evaluate how e-invoicing systems affect corporate performance, most of them focusing on B2G environments, while research on B2B and B2C contexts is limited. The role of regulatory updates and policy compliance in influencing the system evolution has not been sufficiently examined.

Hypotheses we propose for this study are:

H1: Compliance & Legislative changes impact Information Quality.

H2: Compliance & Legislative changes impact System Quality.

H3: Compliance & Legislative changes impact Service Quality.

H4: Information quality impacts User Satisfaction.

H5: System quality impacts User Satisfaction.

H6: Service quality impacts User Satisfaction.

H7: Trust in organization & User Beliefs positively impact User Satisfaction.
H8: User satisfaction impacts Net Benefit.

3. MATHEMATICAL FRAMEWORK AND RESEARCH METHODOLOGY

3.1. Mathematical Modelling

The analytical framework dedicated to evaluating the success of the RO e-Invoice system was based on Structural Equation Modeling (SEM). This advanced statistical technique was selected due to its ability to simultaneously process complex networks of dependencies between latent variables. In this context, theoretical constructs, inaccessible to direct measurement, are rigorously estimated by deriving information from observable indicators, allowing for a deep understanding of the phenomenon studied.

The architecture of a PLS-SEM model is structured on two interdependent levels.

The first, the measurement model (outer model), establishes the correspondence between latent variables and their empirical indicators, whether exogenous or endogenous in nature. Exogenous variables are those latent variables that are not influenced by other variables, but they influence others. They function as predictors or determinants. Endogenous variables are those that are influenced by one or more variables. They act as dependent variables and reflect the outcome of causal relationships.

The second level, the structural model (inner model), centers on evaluating the causal links between constructs. This stage uses path coefficients to quantify the intensity and significance of interactions between latent variables integrated in the study.

Unlike simple linear regression models, SEM allows the decomposition of variance into useful components and measurement errors, providing high precision in testing theoretical hypotheses.

The structural model is explained as a matrix equation:

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (1)$$

η(eta) symbolizes the vector of resultant variables (in our case, User Satisfaction)
ξ(xi) represents the vector of exogenous variables, named predictors (such as Information Quality)
$B(beta)$ and Γ(gamma) are the matrices of structural coefficients indicating the magnitude and direction of influences.
ζ(zeta) represents the residual error at the structural level.

Since quality and satisfaction are abstract (latent) constructs, they are estimated by observable indicators obtained from the research instrument. The measurement model governs the relational architecture between empirical indicators and related constructs, providing the mathematical foundation for assessing convergent validity:

$$x = \Lambda_x\xi + \delta \qquad (2)$$

x is the vector of observed indicators (questionnaire items)
Λ_x(lambda) is the matrix of factor loadings
ξ(xi) is the exogenous latent variable (e.g., System Quality)
δ(delta) represents the measurement error associated with the indicators

Each indicator x_i is a function of the latent variable ξ, weighted by the factor loading Λ_x, to which is added the specific measurement error δ.

The model validation process involved the analysis of internal consistency and convergent validity. To this end, we used Cronbach's alpha and the composite reliability criterion (CR) to certify data homogeneity, completing the evaluation with the determination of the AVE (Average Variance Extracted) index to confirm the representativeness of the constructs.

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum s_i^2}{s_t^2}\right) \qquad (3)$$

$$CR = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum(1-\lambda_i^2)} \qquad (4)$$

$$AVE = \frac{\sum \lambda_i^2}{n} > 0.50 \quad (5)$$

n is the number of indicators associated with the respective construct
s_i^2 is the variance of indicator i
s_t^2 represents the total variance of the aggregate score
Λ_i (Lambda) represents the factor loading of the indicator i

Unlike Cronbach's Alpha, composite reliability (CR) provides a more precise estimate since it abandons the assumption of equal item weights. It recognizes the individual and varied contributions of each indicator to the definition of the theoretical concept. In this analysis, we adopted the critical threshold of 0.7 as an indicator of robust reliability, considering values below 0.6 as insufficient for a rigorous measurement.

Respecting the threshold of 0.5, the AVE indicator demonstrates that the latent variable manages to explain most of the variance of its indicators (over 50%), thus strengthening confidence in the measurement model[21].

Since classical methods for assessing discriminant validity have limitations in detecting construct overlap, we opted for the HTMT-based approach, according to the methodological recommendations of Henseler, Ringle, and Sarstedt [22]. The values must be under 0.90 to confirm that the model has separate dimensions that do not overlap.

To detect collinearity (too much linear dependence) between exogenous variables, we used the Variance Inflation Factor (VIF).

A high VIF suggests that the variable is highly related to other variables in the model, which can lead to instability of the coefficient and difficulties in interpreting the model. For values between 1 and 5, collinearity is moderate, but not problematic. Values greater than 5 indicate collinearity is high and can affect the significance and stability of the model.

For values greater than 10, collinearity is severe, which can lead to serious multicollinearity problems, and the elimination of one of the variables may be necessary.

$$VIF_j = \frac{1}{1 - R_j^2} \quad (6)$$

R_j^2 represents the coefficient of determination obtained by regressing the exogenous variable ξ_j on the other exogenous variables in the model.

The coefficient of determination (R^2) works as a signal of predictive accuracy, reflecting the proportion to which the variance of endogenous constructs (such as User Satisfaction) is accounted for by the cumulative influence of exogenous factors. In essence, it quantifies the structural model's ability to capture and explain the complexity of the phenomenon studied in the context of RO e-Invoice.

$$R^2 = 1 - \frac{\sum (y_{obs} - y_{pred})^2}{\sum (y_{obs} - \bar{y})^2} \quad (7)$$

y_{obs} represent observed values of the endogenous variable η
y_{pred} are values predicted by the structural model based on the Γ coefficients.
$\bar{y}$ is the average of the observed values for the respective construct.

A higher R^2 signifies a good explanatory capacity of the model for that construct. Values over 0.75 are considered very good, values under 0.75 but over 0.50 indicate a moderate variation, while values under 0.50 show a weak impact of the predictors on the construct.

For parameter estimation, the PLS-SEM algorithm was chosen. The choice is mathematically justified by the type of collected data, which often shows deviations from the multivariate normal distribution.

The PLS algorithm works iteratively, optimizing the explained variance of the endogenous constructs through principal component regressions.

$$\min \sum (y_{obs} - y_{pred})^2 \quad (8)$$

The process of estimating parameters in the structural model is grounded in minimizing the sum of squares of the differences between the

observed values (y_{obs}) and the values predicted by the model (y_{pred}). This optimization approach ensures that the explained variance of the endogenous constructs is maximized, providing high predictive power to the system, even under the conditions of a finite sample of users of the RO e-Factura platform.

3.2. Data Collection and Quality Assessment

We obtained the data utilizing an online questionnaire, which was brought to the attention of the system users by e-mail and in special groups on social media platforms.

The questionnaire was constructed based on validated measurement instruments from prior literature regarding the DeLone and McLean Information System Success Model, including the main constructs of quality (information, system, service), user satisfaction, and the construct for net benefit.

Additionally, relevant constructs for trust and digital transformation in public services were integrated and adapted to fit the Romanian e-Invoice (RO e-Factura) context.

To capture both quantitative and qualitative data, we used multiple response types (Likert scales, multiple choice, and open-ended). The number of observed variables is 22, as specified in Table 1.

We obtained 280 valid questionnaires. The respondents are predominantly invoice issuers (45%) and recipients (29%) and they use the system across different types of relationships as follows: 45% in Business to Business (B2B) transactions, involving the exchange of goods or services between two economic operators; 32% in the Business to Consumer (B2C) segment, representing the commercial relationships between a company and a final consumer; 23% in the Business to Government (B2G) relationships, the interactions between an economic operator and public authorities.

To ensure internal consistency, we set the minimum acceptance threshold of 0.70 for Cronbach's Alpha coefficient and CR.

Convergent validity was assessed by the AVE indicator, according to equation 5, where values above 0.50 are considered optimal.

Table 1

Constructs and Items

Construct	Items	Factors
Net Benefit (NB)	NB1	Reduction of bureaucracy
	NB2	Efficiency
	NB3	Comparison with traditional method
System Quality (SEQ)	SEQ1	Usability
	SEQ2	Performance
	SEQ3	Compatibility
	SEQ4	Reliability
Service Quality (SQ)	SQ1	Access Support
	SQ2	Speed of response
	SQ3	Efficiency in response
	SQ4	Reliability
Information Quality (IQ)	IQ1	Clarity
	IQ2	Update
Trust in organization & User Beliefs (T)	T1	Security
	T2	Trust in the nstitution
	T3	Trust in the system
	T4	Transparency
	T5	Trust in electronic systems
Compliance & Legislative Changes (C)	C1	Update
	C2	Update Speed
	C3	Clarity
User Satisfaction US)	US1	Satisfaction Level

4. RESULTS

From the indicators in Table 2, it can be summarized that all the analyzed constructs exhibit adequate reliability and convergent validity, as all values are above the minimum established limits.

All HTMT (Heterotrait-Monotrait Ratio) values, as shown in Table 3, are below the limit of 0.90, ranging between 0.537 (Net Benefits and Service Quality) and 0.895 (Trust and Information Quality), which implies that discriminant validity is generally certified.

The value of 0.895 between Trust and Information Quality is remarkably close to the accepted upper limit, which requires additional attention in interpreting the relationship between these two constructs.

Table 2

Internal consistency and Convergent validity

	Cronbach's alpha	Composite reliability	AVE
Changes	0.856	0.856	0.664
Information Quality	0.858	0.861	0.753

Net Benefits	0.858	0.887	0.684
Service Quality	0.758	0.941	0.513
System Quality	0.823	0.849	0.550
Trust	0.847	0.856	0.531

Table 3

Heterotrait-Monotrait Ratio

	C	IQ	NB	SQ	SEQ	T
C						
IQ	0.782					
NB	0.559	0.754				
SQ	0.657	0.670	0.537			
SEQ	0.790	0.868	0.842	0.788		
T	0.826	0.895	0.807	0.697	0.835	
US	0.787	0.812	0.738	0.667	0.786	0.861

The absence of excessive correlations between the predictor factors is supported by the VIF indicator, whose values are below the threshold of 3. This result eliminates the suspicion of significant multicollinearity, ensuring a stable and robust estimate of the path coefficients.

Outer Loadings values show that most indicators obtained values greater than 0.7, having high validity, except for SEQ3(0.539), SQ2(0.416), SQ3(0.469), and T2(0.599), suggesting a weak contribution to their construct. It may be necessary to remove these indicators or revise them. Cross-loadings analysis reveals increased methodological rigor: the eigenvalues of each item are higher on the core construct than on any other latent construct. This result supports the statistical independence of the variables and validates the conceptual distinction necessary for robust PLS-SEM modeling.

Coefficient of Determination in Regression (R-square indicator) has moderate values for the IQ (61%), NB (54%), SQ (53%), SEQ (63%) components, and a particularly good value for US (76%).

Table 4

Coefficient of Determination in Regression

	R-square	R-square adjusted
Information Quality	0.611	0.610
Net Benefits	0.543	0.542
Service Quality	0.539	0.537
System Quality	0.634	0.633
User Satisfaction	0.764	0.760

Table 5

Path coefficients, T statistics, P value

	Path Coef.	T stat.	P values
Changes -> Information Quality	0.782	15.201	0.000
Changes -> Service Quality	0.734	16.113	0.000
Changes -> System Quality	0.796	18.241	0.000
Information Quality -> User Satisfaction	0.075	0.254	0.799
Service Quality -> User Satisfaction	0.127	0.948	0.343
System Quality -> User Satisfaction	0.109	0.481	0.630
Trust -> User Satisfaction	0.611	2.804	0.005
User Satisfaction -> Net Benefits	0.737	14.951	0.000

Looking at the path coefficients in Table 5, positive and strong relationships (>0.7) are observed between Changes and Information, Service, and System Quality, and between User Satisfaction and Net Benefits. The relation between Trust and User Satisfaction is moderate to strong. Weak relationships with path coefficients close to 0 are between Information Quality (0.075), Service Quality (0.127), System Quality (0.109), and User Satisfaction.

To determine the veracity of the hypotheses, t-statistics and p-values were calculated by running the bootstrapping algorithm with 5000 subsamples. The t-statistic value must be more than 1.96 [11], and the p-value must have a low value, usually below 0.05, to consider the relationship to be significant. Figure 1 illustrates the final conceptual model, completed with the statistical parameters estimated by the PLS-SEM algorithm.

The results in Table 5 show significant relationships between Compliance & Legislative Changes and quality factors, between Trust and User Satisfaction, and between User Satisfaction and Net Benefit, validating hypotheses H1, H2, H3, H7, and H8. Having high p-values, the relations between quality factors and User

Satisfaction are insignificant. Thus, hypotheses H4, H5, and H6 are not supported.

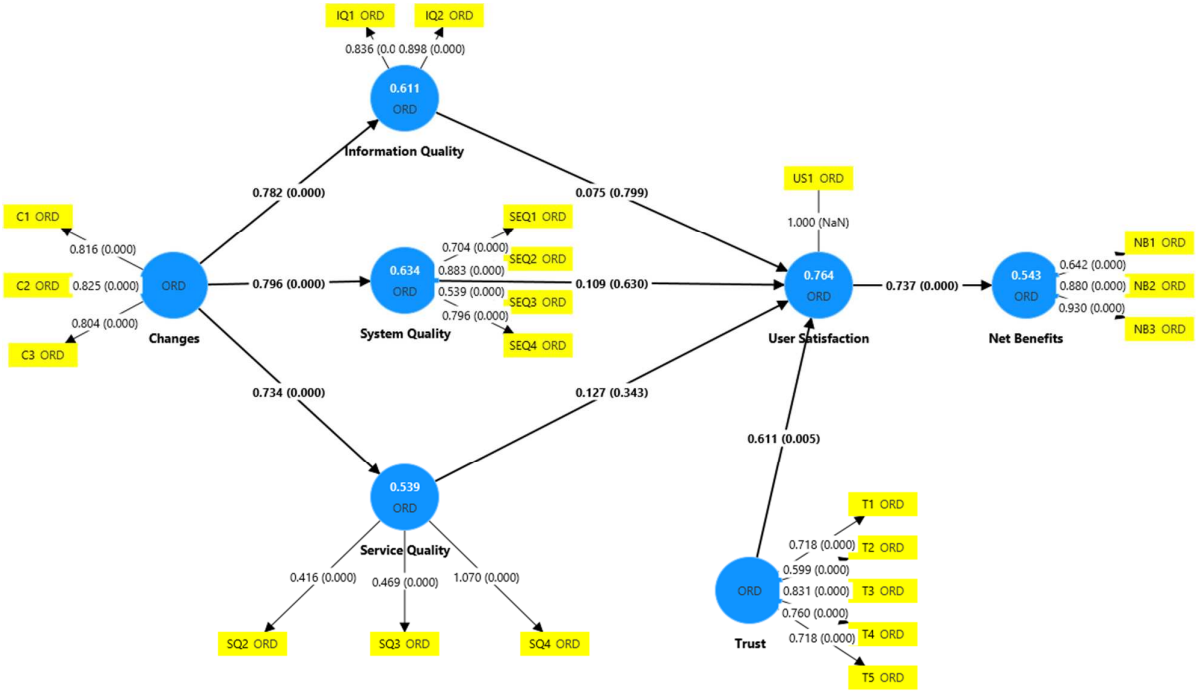

Fig.1. Estimated structural model for the success of RO e-Factura.

5. CONCLUSION

E-Government projects can involve infrastructure, software development, and political changes; assessing progress in this area is a complex process.

We reanalyzed the model by eliminating indicators with weak contribution (SEQ3, SQ2, SQ3) and unifying the system and service quality constructs to simplify the framework. Results "remained consistent, indicating that the unified construct does not alter the model's overall explanatory power or predictive validity." [23]

Despite the theoretical relevance of quality factors (system, service, information) in influencing user satisfaction, their lack of statistical significance in this study may be explained by several contextual and behavioral factors. The mandatory nature of the RO e-Invoice platform may reduce users' sensitivity to quality dimensions; users are legally obliged to utilize the system, which may lead them to evaluate satisfaction based on compliance and outcomes rather than technical performance. Users may have lower expectations regarding public digital services, so that they do not correlate quality with their overall satisfaction. Trust in the organization and beliefs about the security and reliability of the system appear to play a more important role in defining user attitudes than perceptions of usability, accuracy, or service response speed. Another factor that could contribute to these results is the short time elapsed since the system's implementation. Evaluating the model in other e-government systems with varying levels of maturity could provide additional information about its validity. Finally, an alternative explanation for these results may relate to the way constructs were operationalized in the questionnaire. It is possible that the items used to assess the quality dimensions were not sufficiently specific, lacked contextual relevance, or failed to capture the nuances of user experience in a government-mandated digital platform. It is also worth considering whether other variables not included in the original model, such as perceived transparency, the perception of usefulness, personal expectations, or support during the

transition, might serve as more relevant predictors of satisfaction in this context.

The limitations of our study are the short time interval during which we conducted the research and the small number of submitted questionnaires. No pilot survey was tested. Also, no specialists were consulted in designing the questionnaire, so that it could be evaluated in terms of clarity, relevance, and coherence of the questions regarding our objectives.

The findings of this research can bring both theoretical and practical benefits for further research in evaluating the implementation of online and mandatory e-government services and may offer decision-makers valuable insights for the continuous improvement of the services provided.

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Analiza factorilor de succes ai sistemelor digitale impuse legal prin modelarea ecuațiilor structurale: Studiu privind implementarea RO e-Factura

Rezumat: Această lucrare își propune să investigheze succesul implementării sistemului informatic de facturare electronică în România. Cadrul conceptual utilizat pentru acest studiu evaluează implementarea unui sistem informatic în regim de conformare obligatorie, utilizând conceptul de satisfacție a utilizatorilor și adaptând modelul de succes al sistemului informatic al lui DeLone și McLean pentru a include componente precum conformitatea și modificările legislative, precum și încrederea în organizație. Pentru a cuantifica relațiile cauzale dintre variabile, am utilizat metoda SEM PLS. Rezultatele relevă o divergență semnificativă față de modelele clasice, satisfacția utilizatorilor nefiind influențată de factorii de calitate.

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