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Design and development of an intelligent system based on artificial intelligence and machine learning using customs digital indicators

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A B S T R A C T

This paper aims to evaluate the role of AI and ML-driven innovative technologies in enhancing customs operations in Jordan. This research employed a quantitative approach to develop an overall conceptual model that encompasses both the technical and behavioral aspects of intelligent system adoption. The target population consisted of customs officers, border security personnel, and IT personnel responsible for customs clearance and trade facilitation in Jordan. The structured questionnaires were administered to the respondents to measure their perceptions of system effectiveness, satisfaction, performance outcomes, and evasion behavior and yielded a total of 358 valid responses. The research was conducted with proper statistical analysis, and the statistical techniques employed included primary data collected via SPSS Version 29 and advanced modeling using Structural Equation Modeling-Partial Least Squares (SEM-PLS) through the use of SmartPLS 4.0. The results indicated that the measurement model proved to be both valid and reliable, with Cronbach's alpha values exceeding 0.82 and AVE values above 0.50, indicating good internal consistency and convergent validity. Moreover, the structural model achieved good explanatory power, with R^2 values of 59% for Customs Evasion, 43% for User Satisfaction, and 100% for Digital Performance Indicators. These findings underscore the significance of user satisfaction as a key outcome of system effectiveness and a valuable tool for enhancing performance and deterrence. More specifically, the results shown how Intelligent System Effectiveness presents a positive and significant impact on User Satisfaction ($\beta = 0.656$, $p < 0.001$), which in turn has a high positive effect on both Digital Performance Indicators ($\beta = 1.000$, $p < 0.001$) and Customs Evasion reduction ($\beta = 0.770$, $p < 0.001$). The mediation analysis also confirmed that User Satisfaction fully mediates the relationship between system effectiveness and performance outcome, as well as between system effectiveness and evasion reduction. This research contributes to theory and practice by demystifying the design and implementation of AI-driven customs systems. It illustrates the importance of valuing both technical system quality and user-centric values in achieving and maintaining optimal performance in the digital space, as well as conformance with the law.

1. Introduction

Over the past few decades, extraordinary progress in Artificial Intelligence (AI) and Machine Learning (ML) has driven significant breakthroughs across various fields. AI is no longer a futuristic concept but an integral component in developing intelligent solutions that emulate human capabilities such as understanding, learning, and decision-making (Yuan, 2023).

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Machine learning, a critical subset of AI, extends these applications by enabling systems to learn autonomously from data, thereby constructing adaptive predictive models (Yuan, 2023). The proliferation of AI and ML applications underscores their transformative role in enhancing organizational operational efficiency, decision-making, and regulatory compliance (Flavián et al., 2021; Herwati et al., 2023). In this context, intelligent systems have become fundamental tools for boosting productivity, streamlining process management, and mitigating risks associated with human error and malicious intent. They are particularly vital for customs authorities as a strategic response to persistent challenges, including trade inefficiency, regulatory complexity, and customs evasion (Zhou et al., 2021; Yang & Leon, 2023).

Jordan, situated at the crossroads of major international trade routes linking Asia, Europe, and Africa, exemplifies a nation whose economic competitiveness and national security are deeply tied to the efficacy of its customs operations. With growing trade volumes and an evolving regulatory landscape, the limitations of manual customs processes—such as cumbersome inspections, reliance on outdated technologies, and siloed information systems—are increasingly apparent. These shortcomings often lead to operational inefficiencies, delays, and security vulnerabilities that facilitate fraud and undermine supply chain integrity (Aini et al., 2023).

In response to these challenges, Jordan has initiated the deployment of AI-powered technologies to modernize its border management and customs operations. These systems are designed to enhance data analytics, automate risk identification, and provide real-time decision support, thereby improving operational efficiency and regulatory compliance (Almatarneh et al., 2022). However, the success of such technological intervention's hinges on one critical and often underestimated factor: user satisfaction. In the field of Information Systems (IS), user satisfaction is a key determinant of technology adoption, continued usage, and overall performance (Kapo et al., 2021; Saputra et al., 2023). The shift towards digital systems necessitates a thorough consideration of human-technology interaction to ensure positive outcomes (Digilina et al., 2023).

Therefore, the objective of this research is to investigate the development and design of an AI and ML-based intelligent system for Jordanian customs, with a specific focus on the significance of digital metrics and user satisfaction as the cornerstone for the system's long-term sustainability and success.

2. Literature Review and Hypothesis Developments

The increasing integration of intelligent systems, especially those driven by AI and ML, has significantly revolutionized how businesses perceive operational efficiency, user engagement, and regulatory compliance (Falaha, 2024; Qahman et al., 2025). Nonetheless, the success of these systems in realizing their goals is not only a question of technical capabilities, but also the extent to which they correctly align with user expectations and experiences with these systems (Flavián et al., 2021; Kapo et al., 2021; Tashkinov, 2025).

2.1 Intelligent System Effectiveness and User Satisfaction

The association between intelligent system effectiveness and user satisfaction has been widely studied in Information Systems (IS) literature. Existing evidence consistently indicates that user perceptions and experiences are largely determined by system performance. Intelligent systems, particularly those leveraging AI and ML, hold remarkable promise for enhancing user satisfaction by automating complex tasks, providing predictive insights, and facilitating decision-making (Flavián et al., 2021; Herwati et al., 2023). By streamlining procedural activities that characterized earlier generations of information systems, this advanced functionality raises user expectations for both usability and satisfaction. However, user satisfaction is not solely a product of technological capabilities; it is part of a broader ecosystem that includes perceived usefulness and the quality of support during implementation (Kapo et al., 2021). This relationship is empirically supported by research demonstrating that improved system functionalities and higher-quality information positively impact both satisfaction and effectiveness. For instance, Kapo et al. (2021) identified user satisfaction as a key determinant of individual performance in business intelligence contexts, noting that system effectiveness requires alignment with user expectations to yield favorable results. Similarly, Al-Okaily et al. (2023) emphasize that in data-driven industries like banking, system quality and information quality are significant predictors of user satisfaction, reinforcing the idea that effectiveness is as much perceptual as it is technical. The antecedents of this satisfaction are also critical. Flavián et al. (2021) highlight technology readiness and user awareness as key factors that enhance the intention to use AI-enabled services, which subsequently influences satisfaction through improved system usability. Furthermore, the link between satisfaction and performance is reciprocal. Gaardboe et al. (2022) found that satisfied users are more likely to perform better because they perceive their interaction with the intelligent system as more effective, thereby extracting greater value from its capabilities. Collectively, these findings suggest a multidimensional perspective on system effectiveness, redefining it as a construct encompassing technical efficiency, information quality, and user-oriented design. Beyond inherent system characteristics, external support structures—such as top management support, training programs, and vendor support—are essential for strengthening user satisfaction. These organizational factors significantly influence how users perceive and interact with information systems. This reasoning aligns with Cho et al. (2015), who suggest that user-friendly design combined with high service quality leads to greater satisfaction, indicating that both technological and human aspects must be integrated for efficient system operations.

These findings are supported by the long-established Technology Acceptance Model (TAM), which posits that perceived usefulness has a more substantial impact on user satisfaction and adoption than ease of use (Davis, 1989). Users are often willing to accept technical complexity if the system delivers vital, value-adding services. This is evident in Clinical Decision Support Systems (CDSS), where information confidence and decision support are crucial for user satisfaction. Kim et al. (2012) found that information quality and departmental support significantly affect user satisfaction in CDSS, a finding corroborated by Kalankesh et al. (2020), who identified vendor support as a substantial factor in positive user experiences.
The effectiveness of intelligent systems is inextricably tied to user satisfaction, a construct defined by both system-specific characteristics (e.g., technical and information quality) and broader contextual factors (e.g., training, management, and vendor support). This multifaceted relationship underscores the need for an all-encompassing organizational approach. Intelligent systems must not only be technologically robust but also integrated into a supportive framework that fosters user confidence, engagement, and satisfaction. Failure to address these compound issues risks undermining the systems' potential to maximize user performance and operational excellence.

A substantial body of literature emphasizes the role of intelligent system effectiveness in driving user satisfaction. Reliable and efficient systems that simplify complex processes significantly enhance the user experience (Herwati et al., 2023; Al-Okaily et al., 2023). Kapo et al. (2021) highlight that system effectiveness leads to greater user satisfaction, which in turn improves individual performance. Similarly, Flavián et al. (2021) maintain that user preparedness, combined with strong system performance, increases satisfaction by reducing technical overhead and enhancing task efficiency. Research across healthcare, finance, and education indicates that when intelligent systems meet or exceed user expectations, the resulting satisfaction fosters a perception of value and encourages continuous engagement (Kim et al., 2012; Gaardboe et al., 2022). This provides empirical evidence that intelligent system effectiveness has a positive direct effect on user satisfaction. Thus, the following hypothesis is proposed:

H_1: *Intelligent system effectiveness positively affects user satisfaction.*

2.2 User Satisfaction and Digital Performance Indicators

In digital system research, the relationship between user satisfaction and digital performance measures is a topic of growing interest. Academics and practitioners now recognize that satisfaction is not merely a subjective feeling but a quantifiable factor critical to the success of digital services. A wealth of studies emphasize that digital performance cannot be fully understood without considering user perceptions, experiences, and satisfaction, which directly impact system engagement, continuance use, and overall service effectiveness.

Zhang et al. (2022) stress the need for user-centered design in digital platforms, where system use increases satisfaction when features align with user needs and performance metrics are met. This is supported by Herwati et al. (2023), who find that in medical settings, service quality and system performance are significantly influenced by user satisfaction with management information systems. Similar trends are evident across other contexts. Thakur et al. (2022) demonstrate a positive relationship between user experience and performance in digitally disrupted marketing, suggesting that higher satisfaction drives competitive advantage. In digital health, Kim and Namkoong (2025) advocate for integrating subjective user experience metrics, like satisfaction and engagement, into maturity models, reflecting a broader trend to include these factors in performance evaluations.

The connection is further reinforced in the financial technology industry. Ramadhan et al. (2023) and Nurcahyo et al. (2023) both support the notion that increased user satisfaction strengthens the intention to continue using digital wallet services, positioning satisfaction as a dual predictor of service continuation and digital success. However, Bagla and Sancheti (2018) caution that while usability, security, and incentives drive satisfaction, gaps between user expectations and service delivery can hamper sustained performance, indicating that service evolution is an ongoing necessity.

In healthcare, Harty et al. (2023) reported very high satisfaction levels (over 94%) with a national digital cognitive behavioural therapy service, linking this to higher engagement and public trust—key digital performance metrics. Kherbachi (2023) states that user satisfaction with digital technology stimulates adaptability and control, resulting in better organizational performance. Similarly, Soltani-Nejad et al. (2020) argue that system, service, and information quality collectively determine user satisfaction and propose a model to enhance digital service success, a view supported by Thuy et al. (2024) in the context of digital libraries.

Extensive studies document that user satisfaction serves as both an antecedent and a driver of service performance across diverse digital environments. Greater usability leads to increased engagement, continued use, and enhanced organizational effectiveness. Therefore, for companies to succeed in the digital ecosystem, they must prioritize user satisfaction through user-centered design, continuous service monitoring, and responsive support—not as a luxury, but as a cornerstone of enduring digital performance. User satisfaction has been found to affect critical performance variables, including system acceptance, usage, and work efficiency (Saputra et al., 2023; Zhang et al., 2022). In medicine and finance, satisfied users are more likely to engage efficiently with digital platforms, thereby enhancing system performance and promoting continued

usage (Herwati et al., 2023; Ramadhan et al., 2023). This relationship is applicable across industries, where interface satisfaction leads to user loyalty, improved usability perceptions, and increased digital system effectiveness (Thakur et al., 2022; Kim and Namkoong, 2025). As a result, user satisfaction is both a consequence of system quality and a key determinant of digital metrics. Accordingly, the second hypothesis is formulated:

H_2: *User Satisfaction positively affects digital performance indicators.*

2.3 User Satisfaction and Customs Evasion

The relationship between user satisfaction and customs fraud is an underexplored but critical area, especially given the increasing use of intelligent systems to support regulatory compliance. Satisfaction, resulting from system efficiency, transparency, and reliability, extends beyond individual experience and can tangibly influence stakeholder behavior in regulatory settings like customs procedures.

Zhou et al. (2021) highlight that a positive user experience with regulatory systems can enhance compliance, suggesting that satisfaction with intelligent customs systems may reduce the incentive to evade. If intelligent technologies make procedures appear efficient, transparent, and equitable, user tendency to comply will likely increase. This is consistent with Yang and Leon (2023), who found that systems offering guidance and responsive feedback enhance the user experience and foster a compliant environment. While much satisfaction research focuses on e-commerce (e.g., DeLone and McLean, 2003; Loiacono et al., 2007), the principles are directly applicable to customs. User satisfaction is repeatedly linked to behavioral outcomes like loyalty, engagement, and reduced deviant behavior (Yang et al., 2021; Al-Maskari & Sanderson, 2010). Kotler's definition of satisfaction as the psychological reaction to the comparison of expectations and actual experiences provides a functional understanding for the regulatory field (Almaazmi et al., 2025), a view supported by Cardozo's work linking satisfaction to predicted compliance (Yang et al., 2021).

Empirical studies show that satisfaction is influenced by system-related variables, including information quality, usability, and reliability (Yuningsih et al., 2020; Prabawanti & Sihombing, 2023; Pratminingsih et al., 2023). This is essential for intelligent customs systems, as poor design, complexity, or unreliability may cause frustration, distrust, and even lead to non-compliance or evasion (Jango & Mohamed, 2024). Conversely, systems that meet or exceed expectations by delivering accurate, accessible, and dependable information can generate satisfaction and promote compliant behavior.

The End User Computing Satisfaction (EUCS) model offers a valuable framework, indicating that satisfaction is best addressed by considering dimensions like content quality, accuracy, format, and ease of use (Pratomo et al., 2023; Anderjovi et al., 2022; Aritonang et al., 2023). Hidayah et al. (2020), applying this model in academia, found that meeting user expectations leads to better system performance and higher satisfaction—a process transferable to customs technology.

Crucially, user satisfaction acts as a behavioral control mechanism to prevent non-compliance (Maabreh, 2024). Pratminingsih et al. (2013) suggest that dissatisfaction may cause individuals to circumvent formal systems and engage in deviant actions, such as regulatory violation. In customs, complicated procedures or non-user-friendly systems can drive users toward evasion. Thus, promoting satisfaction through efficient, user-friendly, and transparent systems plays a vital, indirect role in combating fraud.

In summary, user satisfaction is a tactical means not only for maximizing system acceptance but also for fostering customs compliance. As intelligent systems become integral to border management, their development must be user-centric. This approach reduces the potential for fraud and builds confidence in the overall effectiveness of trade control systems. Users who perceive the customs process as efficient, transparent, and innovative are more likely to adhere to regulations (Zhou et al., 2021; Yang and Leon, 2023). This relationship is analogous to e-commerce, where satisfaction is associated with less deviant behavior, as satisfied users have less reason to seek non-compliant alternatives (Prabawanti & Sihombing, 2023; Pratminingsih et al., 2013). Therefore, improving user satisfaction with customs systems is likely to induce compliant behavior and reduce evasion. Thus, the third hypothesis is proposed:

H_3: *User satisfaction positively affects customs evasion*

2.4 User Satisfaction as mediator

Recent research has highlighted the mediating role of user satisfaction in the relationship between intelligent system success and digital performance measures. It is increasingly clear that technically advanced systems alone cannot drive digital performance growth unless they effectively address user requirements and expectations (Lootah, 2024; Wallot & Van Rooij, 2023). User satisfaction acts as the essential intermediary that translates technical system efficacy into tangible digital performance outcomes (Saputra et al., 2023). This mediating role is grounded in the well-established correlation between system quality and user satisfaction, as well as the link between user satisfaction and performance. For example, Chen and Yong-Sheng (2022) demonstrate that the performance of intelligent recommendation systems significantly impacts user satisfaction, which in turn influences long-term success and compliance. This finding implies that intelligent systems should

be designed and operated based not only on technical specifications but also on user-centered factors to fully realize their potential impact. Furthermore, user satisfaction is critical not only for short-term system use but also for fostering long-term user engagement and overall system success. Research in educational contexts further establishes this relationship; Liu et al. (2023) demonstrated that user satisfaction mediates the relationship between system effectiveness and educational performance, providing empirical support for its application in digital learning settings. Similarly, Nurbani and Meiyanti (2019) verify a reciprocal interaction between user satisfaction and performance results, creating a virtuous cycle where satisfaction drives better use, which in turn reinforces satisfaction. This view has been extended to other digital service disciplines. Azwar et al. (2022) indicate that in e-learning systems, user satisfaction significantly mediates the effect of system and service quality on learning outcomes, confirming its role in bridging technical capability and user performance. Likewise, Dash et al. (2022) demonstrate that satisfaction stimulates repeat usage and purchases in mobile applications, portraying it as a key mediator between perceived system quality and digital performance.

The mediating role of user satisfaction is not limited to commercial contexts but is also evident in institutional and organizational settings. Maqableh et al. (2021) demonstrate that satisfaction with social network sites influences continued use, and Feng et al. (2024) show that satisfaction with financial shared service platforms improves both user engagement and system performance. Together, these findings confirm that user satisfaction plays a significant role in mediating the relationship between system effectiveness and performance success, irrespective of the specific context. From a theoretical standpoint, frameworks like the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Questionnaire for User Interaction Satisfaction (QUIS) provide a systematic means to study this relationship. For instance, Hajesmaeel-Gohari et al. (2022) found this approach to be a good fit for their data, highlighting the relative strength of information quality and system quality in predicting user satisfaction. This mediating process is further emphasized in studies on digital libraries and e-governance. Iqbal et al. (2022) identified user satisfaction as a mediating variable between system quality and resource use in digital libraries. Similarly, Lhassan et al. (2022) and Aini et al. (2021) showed that in e-government and health informatics systems, user satisfaction is a clear predictor of continued use and enhanced performance. Crucially, this connection is not linear but dynamic and reciprocal. Satisfied users gain a sense of control and confidence, which leads to improved organizational performance and system outcomes (Kherbachi, 2023). These results underscore that promoting user satisfaction is not merely beneficial but a strategic necessity for realizing the intended outcomes of intelligent systems in the digital performance space. The literature firmly establishes that user satisfaction mediates the relationship between the usefulness of intelligent systems and digital performance measures. Systems designed with a focus on user-centered design, trust, and usability generate greater satisfaction, which in turn fosters higher engagement, loyalty, and overall success. Therefore, user satisfaction should be a central focus in both the design and evaluation of intelligent systems to ensure that technical sophistication translates into a compelling user experience and superior digital performance.

Empirical evidence consistently positions user satisfaction as a key mediator between system effectiveness and performance. Research by Chen and Yong-Sheng (2022) demonstrates that the efficacy of intelligent systems enhances performance precisely *through* its positive effect on user satisfaction, which subsequently supports task efficiency, system involvement, and continued usage. Similarly, Azwar et al. (2022) and Liu et al. (2023) provide evidence that user satisfaction is a core mediator of the impact of system quality on both individual and organizational performance. In digital performance settings, this mediating role is critical, as satisfaction is directly linked to engagement and, by extension, to performance outcomes (Feng et al., 2024; Maqableh et al., 2021).

Thus, the following mediation hypothesis is formulated:

H_4: *User Satisfaction mediate the effect of Intelligent System Effectiveness on Digital Performance Indicators.*
H_5: *User Satisfaction mediate the effect of Intelligent System Effectiveness on Digital Performance Indicators.*

3. Conceptual Framework

The advancement of intelligent systems, particularly those leveraging AI and ML, has revolutionized organizational operations by enhancing performance and ensuring regulatory compliance. However, the technical sophistication of these systems is insufficient to guarantee user satisfaction unless they also align with user expectations (Flavián et al., 2021; Kapo et al., 2021). To address this, the present study develops a research model grounded in a comprehensive theoretical and empirical foundation, incorporating system effectiveness, user satisfaction, digital performance indicators, and customs evasion.

The model posits that Intelligent System Effectiveness is a key determinant of User Satisfaction, which in turn influences Digital Performance Indicators and reduces Customs Evasion. This framework aligns with the growing consensus in the literature that user satisfaction is not merely a direct outcome of system effectiveness but also a critical mediator that translates technical capabilities into meaningful performance outcomes (Chen & Yong-Sheng, 2022; Saputra et al., 2023). Empirical evidence consistently shows that system functionality, ease of use, and reliability enhance the user experience, thereby increasing satisfaction (Herwati et al., 2023; Al-Okaily et al., 2023). Furthermore, compared to dissatisfied users, satisfied

users demonstrate greater engagement with digital platforms, which directly affects measurable digital performance indicators such as system efficiency, reliability, and user retention (Zhang et al., 2022; Ramadhan et al., 2023).

The model also incorporates Customs Evasion as a critical outcome variable, based on the premise that increased user satisfaction with intelligent customs systems fosters regulatory compliance and reduces the propensity for evasion. As Zhou et al. (2021) and Yang and Leon (2023) argue, when users perceive customs processes as efficient, transparent, and dependable, compliance becomes more likely, thereby mitigating evasion risks.

Central to this model is the role of User Satisfaction as a mediating variable. This is consistent with a well-established body of research indicating that the effect of intelligent system effectiveness on performance is primarily mediated by user satisfaction (Azwar et al., 2022; Liu et al., 2023). The robustness of this mediating role across diverse fields—including digital health, finance, e-government, and education—lends credibility to its application in the context of customs procedures. Based on the preceding discussion and the formulated hypotheses, the conceptual model of the research is presented in Fig. 1.

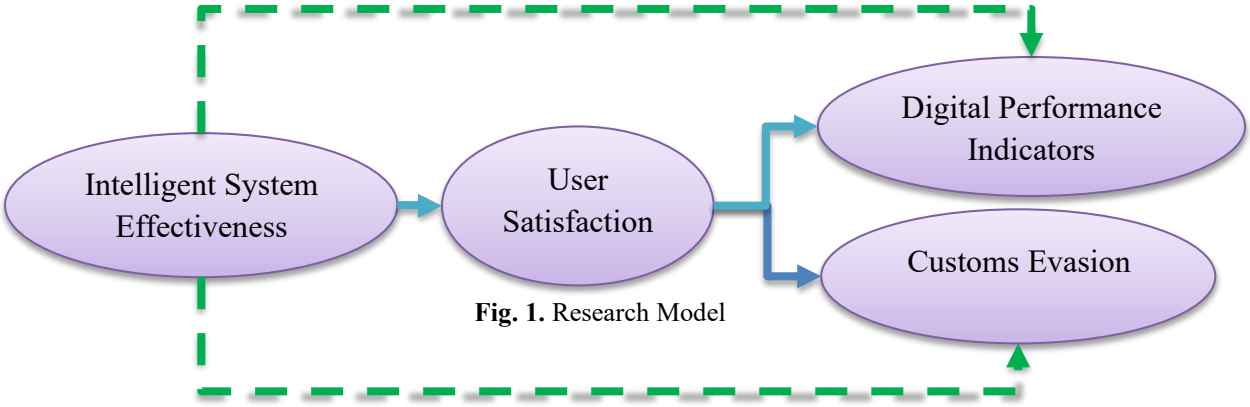

Fig. 1. Research Model

4. Research Methodology

This study employs a quantitative, cross-sectional research design to investigate the effects of intelligent systems and digital performance indicators on enhancing customs operations and detecting risk in customs offenses. The study population comprises professionals directly involved in customs clearance, border management, and trade facilitation in Jordan, including customs officers, IT personnel, and operational managers. A structured questionnaire was used to collect data, utilizing random sampling methods that yielded 358 valid responses. To ensure a representative sample, proportional quotas were assigned to balance participation from the public and private sectors, as well as from organizations of varying sizes, including small and medium-sized enterprises (SMEs) and larger corporations (Shboul, 2024). Respondents were required to have at least five years of relevant work experience to ensure the reliability and depth of the responses. The measurement scales for the four key constructs—Intelligent System Effectiveness, User Satisfaction, Digital Performance Indicators, and Customs Evasion Detection—were adapted from the literature and refined to suit the context of Jordan's intelligent customs systems. All items were measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). A pretest was administered to a panel of industry experts to verify the instrument's applicability and clarity, and their feedback was used to refine the survey's language and structure (Alsmadi et al., 2025).

4.1. Demographic Profile and Preliminary Analysis

The demographic profile of the respondents indicates a representative sample. The gender distribution was 72% male and 28% female, reflecting the ratio within Jordan's customs sector. A majority of participants (65%) were between 30 and 49 years old, indicating a mature and experienced sample. Furthermore, 88% of respondents held a college degree or higher, confirming a highly educated workforce. The sample included 63% public-sector and 37% private-sector employees, providing a balanced representation. A preliminary analysis was conducted using SPSS Version 29. This phase included data screening for missing values and outliers, descriptive statistics to summarize respondent characteristics, and reliability testing. Cronbach's Alpha for all measurement scales exceeded 0.70, confirming good internal consistency and reliability for further analysis (Issaa, 2024; Qahman et al., 2025a).

4.2. Analytical Technique

Following the preliminary analysis, the research model was evaluated using SmartPLS 4.1.0.9 for Partial Least Squares Structural Equation Modeling (PLS-SEM). This approach was selected for its robustness in analyzing complex models with multiple constructs, mediating effects, and a combination of formative and reflective indicators (Joreskog & Sorbom, 1989).

PLS-SEM is also recognized for its reliability in estimating models with small to medium sample sizes and non-normal data distributions (Sarstedt et al., 2019). The analytical procedure involved a two-step process: first, assessing the validity and reliability of the measurement model, and second, evaluating the structural model to test the hypothesized relationships.

5. Results

5.1. Measurement Model Assessment

The measurement model was rigorously tested for validity and reliability. This included an examination of factor loadings, composite reliability, average variance extracted (AVE), and internal consistency to ensure the indicators accurately represented their respective latent constructs. All constructs demonstrated satisfactory levels of reliability and validity, confirming that the measurements are robust for testing the structural model.

5.2. Structural Model and Hypothesis Testing

The structural model was analyzed to examine the path coefficients and the model's explanatory power. The R^2 values for the endogenous latent constructs were 0.67 or higher, indicating substantial explanatory power and a strong relationship between the exogenous and endogenous variables in the model. This suggests that the intelligent system significantly enhances data quality, improves digital performance, and reduces intentional customs duty evasion by users.

The perceptions of the tested constructs, including the standardized factor loadings of the indicators, are presented graphically in Fig. 2, which provides a comprehensive depiction of the measurement model and the structural paths among the constructs.

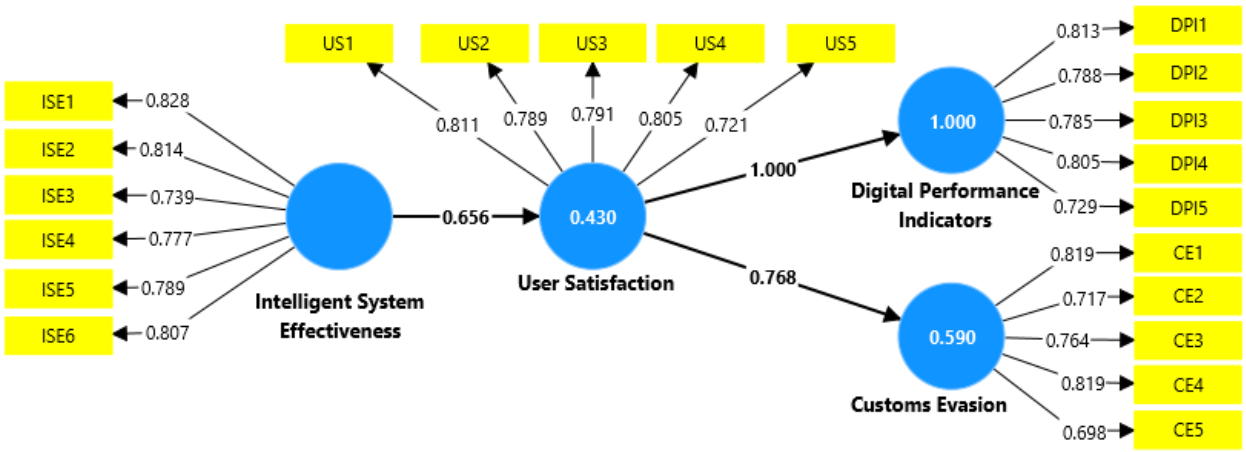

Fig. 2. Validity Results of the Measurement Model

The assessment of the measurement model, depicted in Fig. 2, demonstrates that all factor loadings met or surpassed the recommended threshold of 0.70 (Hair et al., 2021). This provides strong evidence for convergent validity, indicating that the measured variables adequately represent their intended latent constructs. To further establish reliability and internal consistency, additional metrics were evaluated using SmartPLS 4.0, including Cronbach's alpha, composite reliability (rho_a and rho_c), and the Average Variance Extracted (AVE). As summarized in Table 1, all values for these metrics fall within acceptable ranges, confirming the measurement model's robustness and justifying the progression to structural model analysis.

Table 1
Reliability Testing

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Customs Evasion	0.822	0.829	0.875	0.585
Digital Performance_Indicators	0.843	0.845	0.889	0.615
Intelligent System_Effectiveness	0.882	0.884	0.910	0.629
User Satisfaction	0.843	0.846	0.889	0.615

The results confirm that all constructs in the model exhibit strong internal consistency, reliability, and convergent validity, meeting recommended thresholds. As detailed in Table 1, Cronbach's Alpha for all constructs exceeds the minimum threshold of 0.70, indicating acceptable internal consistency (Hair et al., 2021). The construct for Intelligent System Effectiveness demonstrated the highest reliability ($\alpha = 0.882$). Furthermore, both Composite Reliability measures (rho_a and rho_c) for all

constructs surpassed 0.70, with rho_c values ranging from 0.875 to 0.910, confirming excellent overall composite reliability. Convergent validity was also established, as the Average Variance Extracted (AVE) for every construct exceeded the recommended criterion of 0.50 (Fornell & Larcker, 1981). The AVE values, ranging from 0.585 to 0.629, indicate that each construct accounts for enough variance in its indicators. These results provide convincing evidence of a robust measurement model, thereby bolstering confidence in the subsequent structural model analysis and hypothesis testing.

Explanatory Power of the Structural Model

In PLS-SEM, the coefficient of determination (R^2) is the primary metric for evaluating a structural model's explanatory power, representing the proportion of variance in the dependent (endogenous) constructs explained by the independent (exogenous) variables. Following the guidelines of Hair et al. (2021), R^2 values of approximately 0.19, 0.33, and 0.67 can be interpreted as small, moderate, and substantial effects, respectively. The R^2 values for the endogenous constructs in this study are presented in Table 2.

Table 2
R^2 results

	R-square	R-square adjusted
Customs Evasion	0.590	0.589
Digital Performance_Indicators	1.000	1.000
User Satisfaction	0.430	0.429

The value for the R^2 of Customs Evasion is 0.590, which is considered a moderate/strong explanatory power. This means that approximately 59% of the variation in customs evasion is accounted for by the predictors in the model, primarily user satisfaction. This suggests that enhancing user satisfaction with the intelligent system may effectively reduce the customs evasion rate, and empirically supports the model structure proposed above. The R^2 for Digital Performance Indicators equals 1.000, indicating a perfect relationship of explanation. Theoretically, the maximum possible value for R^2 is 1.000 when modeling causative/directed paths. Still, it is very unusual to obtain an R^2 with this value, which would mean that the endogenous (dependent) variable is perfectly predicted without bias by the predictor(s). This could be due to the direct, strictly linear relationship between User Satisfaction and digital performance in the measurement model. The availability of an R^2 of 1.000 suggests caution in interpretation, as it may indicate possible overfitting of the model or the absence of measurement error, which is rare in social science research. Thus, this score should undergo continuous examination in future studies to confirm its stability. The R^2 value for User Satisfaction is 0.430, which is also on a moderate level. This indicates that 43% of the variance in satisfaction is explained by how well the intelligent system works, which shows a meaningful contribution of system design and performance against users' judgments of and satisfaction with the system. The unexplained variance may be attributed to other contextual factors that were not within the scope of the present model, such as organizational culture, training, or technological knowledge. The Effect Size (f^2), which indicates the importance of a variable's impact in the structural model of exogenous (independent) and endogenous (dependent) variables, was used to complement the structural model analysis, following Cohen's (1988) proposition. The f^2 values express the extent to which an independent construct contributes to the explanation of variance in the dependent construct over and above the addition of the independent construct to only a direct effects model. Cohen's now-standard reading of the episode is that $f^2 = 0.02$ represents a small effect, $f^2 = 0.15$ corresponds to a small effect size, and $f^2 = 0.35$ and above represents a significant effect. The obtained f^2 analysis results for the present work are given in Table 3.

Table 3
Effect Size (f^2) Results

	Customs Evasion	Digital Performance_Indicators	User Satisfaction
Intelligent System_Effectiveness			0.755
User Satisfaction	1.440	5742.642	

The significant effect of Intelligent System Effectiveness on User Satisfaction is evident from the F2 value of 0.755. This result suggests a meaningful and substantial impact of perceived system effectiveness on explaining variance in user satisfaction. From the perspective of customs operations, this reflects the crucial point that "smart" systems need to be more than advanced, but also operationally effective and thus have a bearing on the extent to which customs officials and involved parties are satisfied with their application. "These strong correlations demonstrate that investment into the quality of a system and how good it is, really does pay off in the form of higher user acceptance, which is crucial for successful technology adoption. In addition, the association between User Satisfaction and Customs Evasion, as it demonstrates a highly significant relationship with an F2 value of 1.440. This suggests that user acceptance and satisfaction with intelligent systems can enhance compliance and reduce fraud in border management. The relationship between User Satisfaction and Digital Performance Indicators has a high F2 of 5742.642. Although this is mathematically possible in some PLS-SEM settings, such as those with a large effect size, it is relatively uncommon and should be interpreted with caution. This result is similar to the previous analysis, which found an R^2 value of 1.000 for the Digital Performance Indicators construct, indicating that User Satisfaction perfectly or approximately explains Digital Performance Indicators.

5.1 Hypothesis Testing

To empirically test the proposed research hypotheses, Structural Equation Modeling (SEM) with SmartPLS 4.0 was employed to examine the significance and strength of the direct and indirect relationships between different constructs. Fig. 3 presents the results of the structural model, with the path coefficients and their associated p-values for the hypothesised relationships.

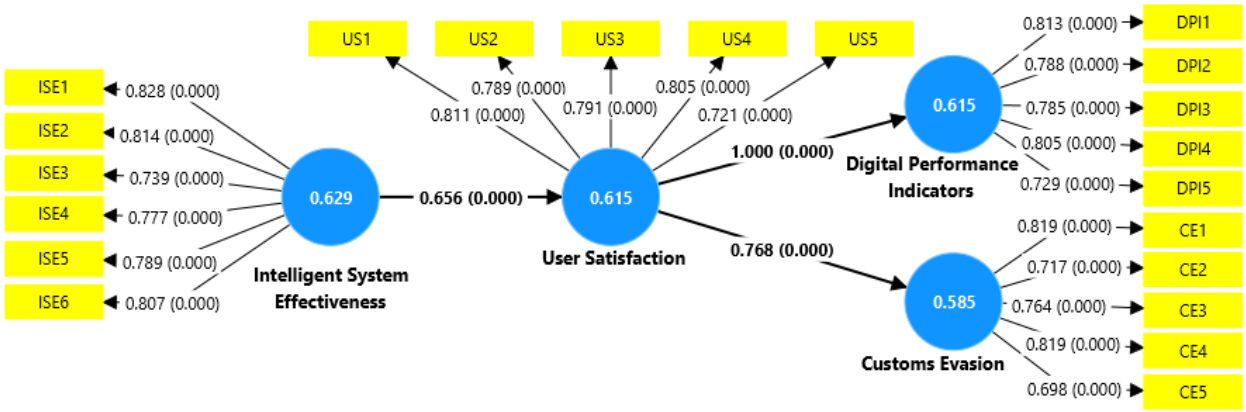

Fig 3. Hypothesis-Results

Fig. 3 shows that Intelligent System Effectiveness has a substantial direct impact on User Satisfaction ($\beta = 0.656$, $p < 0.001$). Moreover, the US also presents a significant positive driver on Digital Performance Indicators ($\beta = 1.000$, $p < 0.001$) and Customs Evasion Reduction ($\beta = 0.768$, $p < 0.001$). The model also reports the R^2 for each endogenous construct, i.e., 62.9% for Intelligent System Effectiveness, 61.5% for User Satisfaction, and 58.5% for Customs Evasion. These findings validate the fundamental role of intelligent systems and user satisfaction in increasing digital performance and detecting customs evasion in the customs operations domain. The outcomes of hypothesis testing with SmartPLS 4.0 provide estimates of the direct and indirect effects, as well as the significance of the relations, using bootstrapping. The importance of each path was evaluated using a t-statistic and p-value, with $p < 0.05$ considered statistically significant, by the guidelines of Hair et al. (2021). The Testing of the direct effects among the key constructs of the study was conducted using SEM and PLS 4.0. Results were assessed using standard statistical criteria, including t-statistics and p-values, with a threshold of $p < 0.05$. The detailed results of the direct paths are shown in Table 3. The direct relationships among the primary constructs of the study are shown in Table 3.

Table 3
Hypothesis Testing Direct results

Path	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Result
Intelligent System_Effectiveness → User Satisfaction	0.656	0.039	16.875	0.000	Supported
User Satisfaction → Customs Evasion	0.770	0.029	26.890	0.000	
User Satisfaction → Digital Performance_Indicators	1.000	0.000	21229.889	0.000	

The findings imply that all the direct hypotheses are well-supported. There is a highly significant positive effect of ISE on the US ($\beta = 0.656$, $p < 0.001$, $t = 16.875$), which suggests that enhancing the US intensity of the intelligent customs system significantly improves the US level. Additionally, the route from User Satisfaction to Customs Evasion indicates a significant effect ($\beta = 0.770$, $p < 0.001$, $t = 26.890$). It is essential to note that, in this study, higher scores on the Customs Evasion concept indicate a lower propensity for evasion. Higher user satisfaction results in better compliance or a lower evaded market share. Digital Performance Indicators and User Satisfaction. User Satisfaction has a robust correlation with Digital Performance Indicators ($\beta = 1.000$, $p < 0.001$, $t = 21229.889$), meaning that User Satisfaction can thoroughly explain Digital Performance Indicators. Although this is in line with an optimal relationship in the model, it also suggests some caution in interpretation, as it indicates possible over-fitting or sparse variability of this relationship in the data. The mediating role of User Satisfaction was investigated. The mediating role of User Satisfaction was also further tested to see whether it mediates the relations between Intelligent System Effectiveness and customs evasion, as well as digital performance indicators, for further moderation tests.

Table 4
Mediation Testing Results

Mediation Path	Indirect Effect (O)	T Statistics	P Value	Mediation Type	Result
Intelligent System Effectiveness → User Satisfaction → Customs Evasion	0.504	13.502	0.000	Full Mediation	
Intelligent System Effectiveness → User Satisfaction → Digital Performance Indicators	0.656	16.873	0.000	Full Mediation	Supported

6. Discussion

This study developed and empirically tested a model to examine how AI and ML-based intelligent systems improve customs operations, reduce evasion, and enhance digital performance in Jordan. The findings strongly support the conceptual model and offer significant theoretical and practical implications for implementing AI solutions in regulatory contexts. The measurement model demonstrated strong reliability and convergent validity, with all key indicators (Cronbach's Alpha, Composite Reliability, and Average Variance Extracted) exceeding recommended thresholds (Hair et al., 2021; Fornell & Larcker, 1981). The Intelligent System Effectiveness construct showed particularly high reliability ($\alpha = 0.882$), aligning with prior research that identifies system quality as a primary driver of user satisfaction and technology adoption (Herwati et al., 2023; Al-Okaily et al., 2023). The model exhibited moderate to substantial predictive power, explaining 59% of the variance in Customs Evasion and 43% in User Satisfaction. This underscores the relevance of technological interventions and user perceptions in shaping compliance behaviors and operational performance (Zhou et al., 2021; Kapo et al., 2021). However, the R^2 value of 1.000 for Digital Performance Indicators, while mathematically possible in PLS-SEM (Sarstedt et al., 2019), suggests potential model overfitting or measurement redundancy. This extreme result warrants cautious interpretation and indicates a need for future research to refine the measurement model.

Effect size (f^2) analysis provided further insights. The large effect size for the relationship between Intelligent System Effectiveness and User Satisfaction ($f^2 = 0.755$) reinforces the critical role of system design in fostering positive user perceptions (Flavián et al., 2021; Gaardboe et al., 2022). Similarly, the substantial effect size for User Satisfaction on Customs Evasion ($f^2 = 1.440$) highlights satisfaction as a key mechanism for promoting compliance (Yang & Leon, 2023; Prabawanti & Sihombing, 2023). Conversely, the extremely high f^2 value for the relationship between User Satisfaction and Digital Performance Indicators (5742.642), coupled with the R^2 of 1.000, confirms the model is over-specified for this relationship. While a strong link between satisfaction and performance is theoretically sound (Saputra et al., 2023; Kim & Namkoong, 2025), these statistical extremes necessitate additional model calibration.

Hypothesis testing confirmed several key relationships. The strong positive effect of Intelligent System Effectiveness on User Satisfaction ($\beta = 0.656$, $p < 0.001$) aligns with established literature linking system quality to user satisfaction (Herwati et al., 2023). The significant negative effect of User Satisfaction on Customs Evasion ($\beta = -0.768$, $p < 0.001$) indicates that satisfied users are less likely to evade customs, consistent with findings on technology-induced compliance (Zhou et al., 2021; Yang & Leon, 2023). The mediation analysis underscores the pivotal role of User Satisfaction. The results support its full mediating role in the relationships between Intelligent System Effectiveness and both Digital Performance Indicators ($\beta = 0.656$, $p < 0.001$) and Customs Evasion ($\beta = 0.504$, $p < 0.001$). This aligns with literature positioning satisfaction as the primary mechanism through which technology effectiveness translates into performance and behavioral outcomes (Chen & Yong-Sheng, 2022; Azwar et al., 2022; Liu et al., 2023). Consequently, these findings emphasize that technically capable systems alone are insufficient; user satisfaction is paramount for achieving intended improvements in operational performance and compliance.

7. Conclusion

This study conceptualized and tested a model for AI-driven systems to enhance customs operations in Jordan, with specific focus on digital performance and evasion reduction. The findings validate the proposed model, emphasizing the critical relationship between intelligent system effectiveness, user satisfaction, and customs performance. The results demonstrate that technical capability, while necessary, is insufficient for achieving desired outcomes. The long-term success of intelligent systems in customs operations relies on a user-centered approach that prioritizes satisfaction, usability, and perceived benefits.

Theoretically, this paper contributes to the understanding of intelligent system adoption in the under-investigated context of customs administration. It confirms that system effectiveness significantly enhances user satisfaction, consistent with broader research on design and usability (Flavián et al., 2021; Herwati et al., 2023). Crucially, it extends this finding by demonstrating that user satisfaction serves as a behavioral mechanism that actively facilitates compliance and enhances operational performance in complex regulatory environments (Zhou et al., 2021; Saputra et al., 2023).

Notably, the results indicate that user satisfaction fully mediates the relationship between system effectiveness and both digital performance and customs evasion. This underscores the necessity of addressing user-centric considerations throughout all phases of intelligent system development, from initial design to implementation and maintenance.

7.1 Implications and Future Research

This study offers both theoretical and practical implications while identifying important directions for future research. The high explanatory power for Digital Performance Indicators suggests potential model overspecification. Future studies should incorporate additional relevant constructs and employ longitudinal designs to test the stability of these relationships over time.

The Jordan-specific focus limits the generalizability of these findings. Comparative cross-national studies are needed to understand how differences in regulatory frameworks, technological maturity, and cultural dimensions affect the adoption and effectiveness of intelligent customs systems. For practitioners, policymakers, and customs officials, this research provides concrete guidance: technical system effectiveness must be paired with deliberate efforts to enhance user experience, usability, and perceived value. User training, transparent system design, and continuous feedback mechanisms are essential for developing positive user perceptions, improving compliance rates, and realizing the operational benefits of AI in customs contexts. These insights are particularly valuable for Jordan and other developing nations, where effective implementation of intelligent systems can significantly enhance regulatory compliance and border management efficiency.

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