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Service Bureau–Enabled Additive Manufacturing Adoption among Indonesian Contract Manufacturing SMEs: A Structural Model Approach

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Abstract: *This study examines the factors influencing service bureau–enabled additive manufacturing (AM) adoption among Indonesian contract manufacturing small and medium-sized enterprises (SMEs). Drawing on the Technology–Organisation–Environment (TOE) framework, a structural model was developed in which cost transparency and lead time reliability influence perceived adoption effectiveness and adoption continuity intention, with perceived adoption effectiveness serving as a mediating variable. A quantitative, cross-sectional survey was administered to managerial-level respondents from Indonesian manufacturing SMEs engaged in contract-based production, and data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The measurement model demonstrated satisfactory reliability and validity, and all five hypothesised relationships were statistically supported. Cost transparency and lead time reliability both exerted positive and significant effects on perceived adoption effectiveness and continuity intention, with cost transparency showing a marginally stronger effect on effectiveness. Perceived adoption effectiveness was the strongest predictor of continuity intention, confirming its mediating role between service bureau characteristics and sustained adoption. The model explained 52% of the variance in perceived adoption effectiveness and 61% of the variance in continuity intention. These findings extend the TOE framework to service-based manufacturing contexts by showing that external service provider characteristics, not only internal organisational readiness, shape SME adoption decisions. The study offers practical guidance for SMEs, AM service bureaus, and policymakers on the importance of pricing clarity and delivery consistency, contributing new empirical evidence from an Indonesian contract manufacturing setting.*

Keywords: *additive manufacturing; service bureau; cost transparency; lead time reliability; adoption continuity intention; PLS-SEM; Indonesian SMEs*

Abstrak: Penelitian ini mengkaji faktor-faktor yang memengaruhi adopsi additive manufacturing (AM) melalui layanan biro jasa pada usaha kecil dan menengah (UKM) manufaktur kontrak di Indonesia. Dengan menggunakan kerangka kerja Technology–Organisation–Environment (TOE), sebuah model struktural dikembangkan di mana transparansi biaya dan keandalan waktu tunggu memengaruhi persepsi efektivitas adopsi serta niat keberlanjutan adopsi, dengan persepsi efektivitas adopsi bertindak sebagai variabel mediasi. Survei kuantitatif cross-sectional dilakukan terhadap responden tingkat manajerial dari UKM manufaktur Indonesia yang bergerak dalam produksi berbasis kontrak, dan data dianalisis menggunakan Partial Least Squares Structural Equation Modelling (PLS-SEM). Model pengukuran menunjukkan reliabilitas dan validitas yang memadai, dan kelima hubungan yang dihipotesiskan terbukti secara statistik. Transparansi biaya dan keandalan waktu tunggu keduanya memberikan pengaruh positif dan signifikan terhadap persepsi efektivitas adopsi dan niat keberlanjutan, di mana transparansi biaya menunjukkan pengaruh yang sedikit lebih kuat terhadap efektivitas. Persepsi efektivitas adopsi merupakan prediktor terkuat bagi niat keberlanjutan, yang mengonfirmasi peran mediasinya antara karakteristik biro jasa dan keberlanjutan adopsi.

Model ini menjelaskan 52% varians dalam persepsi efektivitas adopsi dan 61% varians dalam niat keberlanjutan. Temuan ini memperluas kerangka kerja TOE ke dalam konteks manufaktur berbasis layanan dengan menunjukkan bahwa karakteristik penyedia layanan eksternal—bukan hanya kesiapan organisasi internal—turut membentuk keputusan adopsi UKM. Penelitian ini memberikan panduan praktis bagi UKM, biro jasa AM, dan pembuat kebijakan mengenai pentingnya kejelasan harga dan konsistensi pengiriman, serta memberikan kontribusi berupa bukti empiris baru dari konteks manufaktur kontrak di Indonesia.

Kata kunci: Kata kunci: Pengelolaan Keuangan, Perubahan Regulasi, Kualitas Pelayanan, Kepuasan Pasien

PENDAHULUAN

Additive manufacturing (AM), commonly referred to as 3D printing, has emerged as a transformative technology within modern manufacturing systems. By enabling layer-by-layer production directly from digital designs, AM offers significant advantages, including enhanced design flexibility, reduced material waste, shortened product development cycles, and the potential for decentralised production (Gibson et al., 2020). In recent years, the global AM industry has experienced substantial growth, driven by increasing demand for customised products, rapid prototyping, and digital manufacturing solutions across sectors such as aerospace, healthcare, automotive, and industrial engineering (Wohlers Associates, 2023). Despite its rapid technological advancement and growing industrial applications, the adoption of additive manufacturing at the firm level remains uneven. While large organisations have increasingly integrated AM into production processes, many firms, particularly small and medium-sized enterprises (SMEs), continue to limit its use to prototyping or experimental applications (Durach et al., 2017). This gap between technological potential and practical adoption suggests that challenges extend beyond technical feasibility and are rooted in organisational, strategic, and operational factors (Bai et al., 2020).

SMEs play a critical role in national economies, particularly in manufacturing sectors. In Indonesia, SMEs contribute significantly to economic output and employment, with manufacturing SMEs forming a key component of industrial supply chains, particularly in contract-based production environments. These firms typically operate as suppliers to larger manufacturers, producing customised components or products based on client specifications. As such, they require flexible production capabilities and responsive manufacturing processes to remain competitive. Additive manufacturing has the potential to support these requirements; however, its adoption among SMEs remains limited (Zhou et al., 2016). One key challenge faced by SMEs is the high cost and uncertainty associated with in-house adoption of advanced manufacturing technologies. Additive manufacturing systems often require substantial capital investment, specialised technical expertise, and integration with digital production systems (Baumers et al., 2016). For SMEs operating under resource constraints and narrow profit margins, such investments may be difficult to justify. In addition, limited internal capabilities and uncertainty regarding return on investment further constrain adoption decisions (R. Kumar et al., 2020). Recent developments in manufacturing ecosystems suggest an alternative approach to technology adoption using external service providers. Additive manufacturing service bureaus offer access to AM capabilities on a pay-per-use basis, allowing firms to utilise advanced manufacturing technologies without owning the equipment. This service-based model has the potential to reduce financial barriers and provide SMEs with access to specialised expertise and production capacity (Rayna & Striukova, 2016).

However, while service bureau–enabled adoption presents a promising pathway, empirical understanding of how SMEs engage with such models remains limited. Existing research on additive manufacturing has largely focused on technological capabilities or internal adoption, with insufficient attention given to service-based adoption mechanisms, particularly within SME contexts. Furthermore, studies rarely examine how operational factors such as cost transparency, lead time reliability, and perceived effectiveness influence SMEs' evaluation of service bureau engagement (Ford & Despeisse, 2016). Given the importance of SMEs in manufacturing supply chains and the increasing relevance of service-based production models, there is a need to develop a deeper understanding of how SMEs adopt additive manufacturing through external providers. This study therefore focuses on service bureau–enabled AM adoption among Indonesian contract manufacturing SMEs, aiming to provide empirical insights into the organisational, operational, and relational factors that shape adoption outcomes.

Literature Review

Understanding additive manufacturing (AM) adoption among manufacturing SMEs requires a theoretical framework that can comprehensively explain how technological, organisational, and environmental factors influence firm-level decision-making. Given the complexity of adoption in service-based manufacturing contexts, relying on a single theoretical perspective is insufficient. This study therefore adopts the Technology–Organisation–Environment (TOE) framework as its primary theoretical lens, complemented by insights from the wider technology adoption and continuance literature, to provide a holistic explanation of service bureau–enabled additive manufacturing adoption. The Technology–Organisation–Environment (TOE) framework serves as the primary underpinning theory of this study. Originally developed to explain technology adoption at the organisational level, the TOE framework posits that adoption decisions are shaped by three contextual dimensions: technological characteristics, organisational readiness, and environmental conditions. The technological dimension refers to the perceived benefits and complexity of the technology, the organisational dimension encompasses firm resources, capabilities, and internal processes, while the environmental dimension includes competitive pressure, industry structure, and external support systems (Baker, 2012). The TOE framework has been widely applied in studies of digital transformation, Industry 4.0 adoption, and advanced manufacturing technologies, particularly in SME contexts. Its strength lies in its ability to capture multiple dimensions of adoption beyond purely technological considerations. For SMEs, where adoption decisions are often constrained by limited resources and external pressures, the TOE framework provides a structured approach to understanding how these constraints influence behaviour (Mittal et al., 2020).

Hypothesis Development

Cost Transparency

Cost transparency refers to the clarity and predictability of pricing structures associated with service bureau–enabled AM. In SME contexts, financial constraints and risk sensitivity make cost visibility a critical factor in adoption decisions. From a TOE perspective, cost considerations fall within the organisational dimension, and transparent pricing reduces uncertainty and enables SMEs to evaluate the economic feasibility of AM adoption more effectively. Recent empirical evidence reinforces the centrality of cost-related criteria in adoption and outsourcing decisions. In a decision-support study of additive manufacturing service bureau selection, economic criteria such as pricing structure and cost predictability carried substantial weight in firms' evaluation and selection of external AM providers, alongside quality and delivery considerations (Ghuge & Akarte, 2024). Similarly, a study of digital technology adoption among Indonesian SMEs found that adoption cost was a

significant determinant of technology uptake, with firms that perceived costs as unpredictable or opaque reporting markedly lower adoption intentions (Faiz et al., 2024). These findings are consistent with earlier evidence that the capital intensity and cost uncertainty of advanced manufacturing systems constrain SME investment decisions (Baumers et al., 2016), and that limited internal capability to interpret return on investment further amplifies the importance of cost clarity for resource-constrained firms (R. Kumar et al., 2020). Taken together, this body of research suggests that when SMEs can clearly anticipate and verify the costs associated with an external AM provider, they are better positioned to judge the effectiveness of adoption and to commit to a continued relationship with that provider. Accordingly:
H1a: Cost transparency positively influences perceived adoption effectiveness.
H1b: Cost transparency positively influences adoption continuity intention.

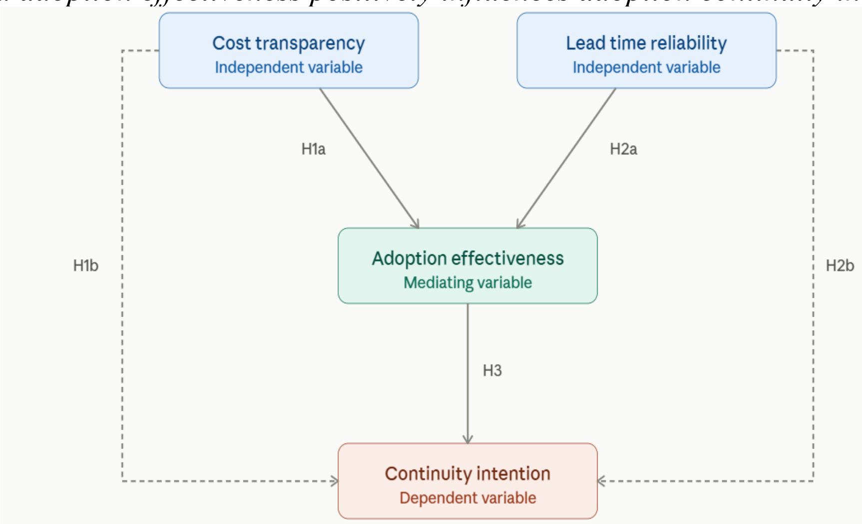
Lead Time Reliability and Adoption Outcomes

Lead time reliability refers to the consistency and predictability of production and delivery timelines provided by service bureaus. Within the TOE framework, environmental pressures such as customer expectations and competitive demands make delivery performance a key determinant of adoption decisions, as reliable lead times reduce operational risk and enhance trust in external providers. This proposition is supported by recent supply chain research. In a study of manufacturing firms operating in a developing-country context, delivery reliability was found to partially mediate the relationship between transportation logistics strategy and supply chain responsiveness, underscoring its role as a critical operational lever (AL-Shboul, 2022). In an Indonesian setting, supply chain responsiveness, including the reliability of the logistics process, was shown to significantly influence firms' ability to satisfy and retain business customers (Paramitha et al., 2023). Within the specific context of additive manufacturing outsourcing, delivery-related criteria, alongside cost and quality, were identified as key inputs into firms' service bureau selection decisions, reflecting the operational risk that unreliable lead times pose to adopting firms (Ghuge & Akarte, 2024). More broadly, supply chain resilience research has emphasised that firms operating with limited buffer capacity, a common condition among SMEs, are disproportionately exposed to disruption when external partners cannot guarantee consistent delivery performance (Ivanov & Dolgui, 2020). Collectively, these studies suggest that SMEs place considerable weight on the predictability of service bureau delivery timelines when evaluating both the effectiveness of AM adoption and their intention to continue the relationship, accordingly:
H2a: Lead time reliability positively influences perceived adoption effectiveness.
H2b : Lead time reliability positively influences adoption continuity intention.

Perceived Adoption Effectiveness and Continuity Intention

Perceived adoption effectiveness reflects SMEs' evaluation of the benefits derived from AM adoption, including improvements in production flexibility, product quality, and responsiveness to client requirements. Technology adoption literature suggests that positive performance outcomes increase the likelihood of continued usage, a relationship rooted in the expectation-confirmation tradition of information systems continuance research (Bhattacherjee, 2001). More recent studies confirm the robustness of this relationship across contexts relevant to SMEs. Among small and medium enterprises using digital accounting systems, perceived usefulness was found to significantly and positively influence users' intention to continue using the system, even after accounting for system and information quality (Al-Hattami & Almaqtari, 2023). In a study of Indonesian entrepreneurs, perceived usefulness was shown to mediate the relationship between users' evaluation of a technology and their intention to continue adopting it, reinforcing the mediating role that effectiveness perceptions play between antecedent conditions and continuance outcomes (Putro &

Takahashi, 2024). Similarly, research on technology-driven organisational change has argued that continuance is best understood not as a one-time decision but as an ongoing evaluation shaped by the cumulative value that a technology or service delivers (Verhoef et al., 2021). Applied to the service bureau context, these findings imply that Indonesian contract manufacturing SMEs that perceive tangible benefits from AM adoption, such as improved lead times, cost savings, or design flexibility, are more likely to sustain and potentially expand their engagement with service bureau providers, accordingly:
H3: Perceived adoption effectiveness positively influences adoption continuity intention.



METHODOLOGY

This study employs a quantitative, cross-sectional research design to investigate the factors influencing service bureau–enabled additive manufacturing adoption among Indonesian contract manufacturing SMEs. A quantitative approach is selected because it enables the measurement of relationships between variables and supports hypothesis testing using statistical techniques, which aligns with the objectives of this study (Creswell, 2018). This study adopts a positivist research philosophy, which is appropriate for examining relationships between measurable variables and testing theoretically derived hypotheses. Positivism assumes that reality is objective and can be observed and analysed through empirical data using statistical methods. This approach is widely applied in technology adoption and organisational research, particularly when the objective is to test causal relationships between constructs (Bell et al., 2022). The target population for this study consists of manufacturing small and medium-sized enterprises (SMEs) operating in Indonesia, with a specific focus on firms engaged in contract-based production environments. These SMEs typically function as suppliers within larger industrial supply chains, producing components, parts, or finished products based on client specifications. Such firms are characterised by high dependence on operational efficiency, cost control, and delivery performance, making them highly relevant for examining additive manufacturing (AM) adoption.

The sample for this study consists of managerial-level respondents from Indonesian manufacturing SMEs engaged in contract-based production environments. Specifically, the targeted respondents include owners, managing directors, operations managers, engineering managers, and production managers, as these individuals are directly involved in production planning, supplier coordination, and technology adoption decisions. Their roles require them to evaluate operational performance, manage external service providers, and make strategic decisions regarding manufacturing technologies, making them well-positioned to provide informed and reliable responses. This study employs a purposive sampling technique, a nonprobability sampling method used to select respondents based on specific characteristics relevant to the research objectives. Purposive sampling is particularly appropriate for this study because it requires respondents who possess specialised knowledge and experience related to additive manufacturing (AM) adoption and engagement with service bureau providers. The data collected in this study were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) with SmartPLS 4.0 software. PLS-SEM was selected as the primary analytical technique due to its suitability for predictive research, its ability to handle complex models involving multiple constructs, and its robustness when applied to small to medium sample sizes. This makes it particularly appropriate for studies involving SMEs, where large sample sizes may be difficult to obtain. In addition, PLS-SEM does not require strict assumptions regarding data normality and can analyse both direct and indirect relationships simultaneously. Given that this study examines two independent variables and their influence on perceived adoption effectiveness and adoption continuity intention, PLS-SEM provides a flexible and effective approach for testing the proposed conceptual model.

RESULTS

A total of 115 valid responses were obtained from managerial-level employees across the participating manufacturing SMEs. As shown in Table [X], the sample is evenly spread across managerial functions, with Operations Managers forming the largest group (n = 45, 39%), followed closely by Engineering Managers (n = 40, 35%) and Owners (n = 30, 26%). This distribution suggests that the responses were obtained predominantly from individuals directly responsible for day-to-day production and technical decision-making, rather than from ownership alone, which strengthens the operational relevance of the data collected. In terms of work experience, most respondents (n = 60, 52%) had less than five years of experience, while the remaining respondents were evenly split between 5–10 years (n = 27, 23%) and more than 10 years of experience (n = 28, 24%).

Table 1. Demographic profile of respondents

Variable	Category	Frequency	Percentage (%)
Position	Owner	30	26
	Operations Manager	45	39
	Engineering Manager	40	35
Total		**115**	**100**
Experience	< 5 years	60	52
	5–10 years	27	24
	> 10 years	28	13
Total		**115**	**100**
Company Size	1–5 employees	13	11
	6–10 employees	84	73
	Above 10 employees	18	16
Total		**115**	**100**

This indicates that, although the sample is weighted toward relatively less experienced managers, nearly half of the respondents (47%) had five or more years of industry experience, providing a reasonable balance of newer and more seasoned perspectives on additive manufacturing adoption decisions. With respect to company size, the sample is dominated by firms employing between 6 and 10 employees (n = 84, 73%), with smaller proportions of firms employing 1–5 employees (n = 13, 11%) and more than 10 employees (n = 18, 16%). This concentration indicates that most participating firms are very small enterprises, which is broadly consistent with the profile of contract manufacturing SMEs and reinforces the relevance of examining resource-constrained, service-based technology adoption pathways such as additive manufacturing service bureaus in this context. Indicator reliability was assessed by examining the outer loadings of each indicator on its corresponding latent construct. According to Hair and Alamer (2022), indicator loadings greater than 0.70 indicate that an indicator adequately represents the underlying construct. As shown in Table 2, all measurement items demonstrated outer loadings above the recommended threshold of 0.70, indicating satisfactory indicator reliability. Therefore, all indicators were retained for further analysis.

Table 2. Outer loadings of measurement items

Construct	Indicator	Loading
Cost Transparency	CT1	0.82
	CT2	0.79
	CT3	0.84
	CT4	0.80
Lead Time Reliability	LTR1	0.85
	LTR2	0.81
	LTR3	0.78
	LTR4	0.83
Perceived Adoption Effectiveness	PAE1	0.87
	PAE2	0.84
	PAE3	0.82
	PAE4	0.80
Adoption Continuity Intention	ACI1	0.89
	ACI2	0.85
	ACI3	0.83
	ACI4	0.84

Internal Consistency Reliability

Internal consistency reliability was assessed using Cronbach's Alpha (CA) and Composite Reliability (CR). These metrics evaluate the consistency of items used to measure each latent construct. As shown in Table 3, all four constructs exceeded the recommended thresholds of 0.70, confirming satisfactory internal consistency reliability.

Table 3. Internal consistency reliability

Construct	Cronbach's Alpha	Composite Reliability
Cost Transparency	0.86	0.90
Lead Time Reliability	0.87	0.91
Perceived Adoption Effectiveness	0.89	0.92
Adoption Continuity Intention	0.90	0.93

Convergent Validity

Convergent validity assesses the extent to which indicators of a construct converge to measure the same concept. This is evaluated using the Average Variance Extracted (AVE). As shown in Table 4, all constructs recorded AVE values above the 0.50 threshold, confirming adequate convergent validity.

Table 4. Convergent validity (AVE)

Construct	AVE
Cost Transparency	0.68
Lead Time Reliability	0.71
Perceived Adoption Effectiveness	0.74
Adoption Continuity Intention	0.77

Discriminant Validity

Discriminant validity assesses whether constructs are empirically distinct from each other. In this study, discriminant validity was evaluated using the Heterotrait–Monotrait ratio (HTMT). As shown in Table 5, all HTMT values were below the conservative threshold of 0.85 (Henseler et al., 2015), confirming that the four constructs are empirically distinct.

Table 5. Discriminant validity (HTMT ratio)

Construct	CT	LTR	PAE	ACI
CT	—			
LTR	0.63	—		
PAE	0.64	0.67	—	
ACI	0.61	0.63	0.72	—

Path Coefficients and Hypothesis Testing

The structural relationships among the constructs were assessed based on the standardised path coefficients (β), t-values, and p-values obtained from the bootstrapping procedure. A t-value greater than 1.96 indicates statistical significance at the 5% level. Table 6 summarises the results of the hypothesis testing for the five hypothesised paths (H1a, H1b, H2a, H2b, and H3). The results indicate that all five hypothesised relationships are statistically significant. Cost transparency (H1a, H1b) and lead time reliability (H2a, H2b) both have positive and significant effects on perceived adoption effectiveness and adoption continuity intention. Among the two predictors of perceived adoption effectiveness, cost transparency exhibits the stronger effect (β = 0.31) relative to lead time reliability (β = 0.27), suggesting that predictable and transparent pricing structures play a slightly more prominent role than delivery consistency in shaping SMEs' evaluation of additive manufacturing adoption, although both factors are clearly influential. Furthermore, perceived adoption effectiveness shows the strongest overall effect in the model, exerting a substantial positive influence on adoption continuity intention (H3, β = 0.45), indicating that SMEs are more likely to continue or expand their use of additive manufacturing service bureaus when they perceive the adoption outcomes as beneficial.

Table 6. Path coefficients and hypothesis testing results

Hypothesis	Path	Beta (β)	T-value	P-value	Result
H1a	Cost Transparency → Perceived Adoption Effectiveness	0.31	3.42	0.001	Supported
H1b	Cost Transparency → Adoption Continuity Intention	0.18	2.11	0.035	Supported
H2a	Lead Time Reliability → Perceived Adoption Effectiveness	0.27	3.10	0.002	Supported
H2b	Lead Time Reliability → Adoption Continuity Intention	0.16	2.03	0.042	Supported
H3	Perceived Adoption Effectiveness → Adoption Continuity Intention	0.45	5.72	0.000	Supported

Coefficient of Determination (R^2)

The explanatory power of the structural model was evaluated using the coefficient of determination (R^2) for the endogenous constructs. According to Hair and Alamer (2022), R^2 values of 0.25 indicate weak explanatory power, 0.50 indicate moderate explanatory power, and 0.75 indicate substantial explanatory power.

Table 7. Coefficient of determination (R^2)

Endogenous Construct	R^2
Perceived Adoption Effectiveness	0.52
Adoption Continuity Intention	0.61

The results show that the model explains 52% of the variance in perceived adoption effectiveness and 61% of the variance in adoption continuity intention, indicating moderate explanatory power for both endogenous constructs.

DISCUSSION

This section discusses the results of hypothesis testing in relation to the two antecedent constructs (cost transparency and lead time reliability), the mediating construct (perceived adoption effectiveness), and the outcome construct (adoption continuity intention). The findings indicate that cost transparency has a positive and significant effect on both perceived adoption effectiveness (H1a) and adoption continuity intention (H1b). This result supports both hypotheses and suggests that SMEs place strong emphasis on pricing clarity when evaluating additive manufacturing services. This finding aligns with the organisational dimension of the TOE framework, where financial considerations play a critical role in shaping technology adoption decisions. SMEs typically operate under tight budget constraints, making cost predictability essential for operational planning and risk management. Transparent pricing reduces uncertainty and enhances decision confidence, thereby improving perceived effectiveness. The result is consistent with recent evidence that cost-related criteria carry substantial weight in SMEs' technology adoption and service provider selection decisions (Faiz et al., 2024; Ghuge & Akarte, 2024). In contrast to large firms, which may absorb cost fluctuations more easily, SMEs are more sensitive to pricing uncertainty, reinforcing the importance of cost transparency in service-based adoption (Agostini & Nosella, 2020).

Lead time reliability was found to have a significant positive effect on both perceived adoption effectiveness (H2a) and adoption continuity intention (H2b). This indicates that consistent and predictable delivery performance is critical in shaping SMEs' evaluation of service bureau–enabled additive manufacturing. This finding reflects the environmental dimension of the TOE framework, where external pressures such as customer expectations and competitive requirements influence adoption behaviour. In contract manufacturing environments, failure to meet delivery deadlines can result in penalties and loss of business, making reliability a key consideration. The result supports recent literature emphasising that delivery reliability is a major factor in outsourcing and supply chain decisions (AL-Shboul, 2022; Paramitha et al., 2023). Compared to large firms, SMEs often lack buffer capacity to manage delays, making them more dependent on reliable service providers. This reinforces the importance of lead time reliability in service-based adoption models (Ivanov & Dolgui, 2020). The results confirm that perceived adoption effectiveness has a significant positive effect on adoption continuity intention (H3), the strongest relationship observed in the structural model. This indicates that SMEs are considerably more likely to continue or expand their use of additive manufacturing services when they perceive the technology as effective. This finding is consistent with recent technology continuance literature, which shows that perceived usefulness or effectiveness is a robust predictor of continuance intention among SME users of digital systems (Al-Hattami & Almaqtari, 2023; Putro & Takahashi, 2024). It also reinforces the process-based view of adoption, where adoption is not a one-time decision, but an ongoing evaluation process shaped by the cumulative value a technology delivers (Verhoef et al., 2021).

Conclusion

This study examined additive manufacturing adoption among Indonesian contract manufacturing SMEs, focusing on service bureau–enabled adoption pathways. Using PLS-SEM, the study tested a five-hypothesis structural model linking cost transparency and lead time reliability to perceived adoption effectiveness and adoption continuity intention. The findings demonstrate that both cost transparency and lead time reliability positively and significantly influence perceived adoption effectiveness and continuity intention, and that perceived adoption effectiveness in turn strongly drives continuity intention, with the model explaining 52% and 61% of the variance in these two outcomes respectively. The study highlights the importance of operational transparency and reliability in shaping how Indonesian SMEs evaluate and sustain their engagement with additive manufacturing service bureaus and provides both theoretical and practical insights into technology adoption in service-based manufacturing contexts. Overall, the findings contribute to a more nuanced understanding of how SMEs engage with additive manufacturing and provide a foundation for future research and industry practice.

Implications

Theoretical Contributions

This study makes several important theoretical contributions to the literature on technology adoption, advanced manufacturing, and SME research by extending existing frameworks to better capture service-based manufacturing contexts. First, the study contributes to the Technology–Organisation–Environment (TOE) framework by extending its application from traditional ownership-based adoption models to service bureau–enabled additive manufacturing adoption. While the TOE framework has been widely used to explain technology adoption decisions, prior studies have largely focused on internal adoption contexts, where firms invest in and operate technologies within their organisational boundaries. This study advances the framework by demonstrating that, in service-based manufacturing environments, adoption decisions are shaped not only by internal organisational readiness but also by external service provider characteristics, namely cost transparency and lead time reliability. By empirically validating these relationships, the study provides a more context-sensitive application of TOE and highlights the importance of operational dimensions in shaping SME adoption behaviour.

Second, by confirming perceived adoption effectiveness as a significant mediator between service bureau characteristics and continuity intention (H3), the study extends technology continuance theorising, typically developed in information systems contexts, into the domain of service-based advanced manufacturing adoption (Al-Hattami & Almaqtari, 2023; Bhattacherjee, 2001).

Practical Implications

The findings of this study provide several important practical implications for manufacturing SMEs, additive manufacturing (AM) service bureaus, and policymakers involved in industrial development and digital transformation initiatives. These implications are particularly relevant within the context of Indonesian contract manufacturing SMEs, where firms operate under resource constraints and depend heavily on external production capabilities. For manufacturing SMEs, the results highlight the importance of carefully evaluating service bureau partners based on pricing clarity and delivery performance. The significant effects of cost transparency and lead time reliability suggest that SMEs should prioritise service providers that offer clear pricing structures and consistent delivery performance. Transparent pricing enables SMEs to better estimate production costs and manage financial risks, which is especially critical in contract manufacturing environments characterised by tight margins and competitive pricing pressures. Similarly, reliable lead times support production planning and help firms meet contractual delivery obligations, thereby reducing operational uncertainty and maintaining client satisfaction. For AM service bureaus, the findings suggest that competitive advantage can be gained not only through technical capability but also through operational transparency and delivery consistency, both of which strongly shape SME clients' perceptions of adoption effectiveness and their willingness to sustain the relationship. For policymakers, the results point to the value of supporting standardised, transparent pricing benchmarks and service-level agreements within the AM service bureau ecosystem, which could help lower the perceived risk of adoption for Indonesian manufacturing SMEs.

Limitations and Future Research

This study is subject to several limitations that should be considered when interpreting the findings, each of which points to a corresponding direction for future research. First, the study focuses specifically on Indonesian contract manufacturing SMEs, which may limit the generalisability of the findings to other institutional or industrial contexts; future studies could therefore extend this research through comparative designs across emerging and developed economies. Second, the cross-sectional design captures relationships at a single point in time and does not reflect how adoption behaviour may evolve as firms gain experience with service bureaus; longitudinal designs would allow future research to examine learning effects and potential transitions from service bureau engagement toward in-house AM adoption. Third, the study relies on self-reported data collected from managerial respondents, which may be subject to common method or respondent bias, as participants may report perceptions rather than objective performance outcomes. Finally, the present model was deliberately kept parsimonious, focusing on cost transparency, lead time reliability, and perceived adoption effectiveness; future studies could enrich the model by incorporating additional constructs such as digital maturity, organisational culture, or competitive pressure to further strengthen the explanatory power of the TOE framework in advanced manufacturing contexts.

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