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ADOPTION READINESS OF ASSISTIVE SURGICAL ROBOTIC TECHNOLOGIES IN INDONESIAN NEUROSURGERY: AN EMPIRICAL ASSESSMENT USING THE READINESS INDEX

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Abstract. The global expansion of assistive surgical robotic technologies creates an important opportunity for emerging healthcare markets, yet the adoption readiness of specialist users is still not well understood. This study assesses the readiness of neurosurgeons in Indonesia toward assistive robotic technologies and identifies practical pathways for accelerating adoption. A mixed-method exploratory design was used, combining Likert-scale survey data and qualitative thematic analysis from 41 practicing neurosurgeons across Indonesia. Rogers' Diffusion of Innovation framework guided the study. A Readiness Index developed for this study, calculated as the ratio of mean enabler scores to mean barrier scores multiplied by 100, was used to profile readiness and adopter segments. The findings show high awareness (mean 4.199) and conditionally favorable perceptions, with perceived enablers (mean 4.138) slightly outweighing barriers (mean 3.920). Financial constraints were the dominant barriers, while government support and structured training were the strongest enablers. The Readiness Index produced a mean of 108.5, with 26.8% High Readiness, 48.8% Medium, and 24.4% Low. The Early Majority segment was only 4.9%, indicating that mainstream diffusion conditions have not yet formed. Proposed pathways include a neuro-first strategy, capability-building programs, hybrid financing, and multi-stakeholder ecosystem coordination.

Keywords: adoption readiness, assistive robotic technology, neurosurgery, diffusion of innovation, and Indonesia

Introduction

The global development of healthcare technology has substantially transformed the landscape of complex surgical practice. Among the most consequential advances is the rise of assistive robotic technologies, systems that augment surgical performance through enhanced visualization, precision support, ergonomic improvement, and digital workflow integration, while preserving the surgeon's direct operative control. Unlike fully autonomous robotic platforms, which require significant infrastructure and institutional reconfiguration, assistive technologies provide a more incremental and contextually feasible entry point for healthcare systems at different levels of technological maturity (Rivero-Moreno et al., 2023; Shah, 2021).

This distinction has pragmatic implications. Assistive robotic technologies like robotic digital microscopes, neuronavigation systems and precision visualization platforms can be integrated into existing surgical workflows, need relatively lower capital investment, and allow for selective adoption at the specialty rather than full commitment at the institutional level. This opens the possibility for assistive technologies to be a more viable entry point for surgical modernization in developing healthcare markets such as Indonesia compared to large fully robotic platforms (Hoeckelmann et al., 2015; WHO, 2023).

Indonesia's national healthcare transformation agenda identifies advanced surgical technology as a long-term modernization priority. The government has designated pilot Robotic Surgery Centers at selected national referral hospitals and has incorporated robotics, artificial intelligence and digitally integrated clinical tools in its health system upgrading strategy (Ministry of Health Republic of Indonesia, 2023). But user-side readiness has not kept pace with these commitments. In a study at one of the government-designated robotic surgery centers, Rudiman et al. (2023) found that all 43 surgeons recruited across departments had no prior experience with robotic surgical procedures. Formal designation has not been matched by equivalent investment in clinical capability development.

This gap is especially relevant in neurosurgery. This specialty requires high precision, stable intraoperative visualization, and fine motor coordination, with technologies that enhance operatory consistency and ergonomic control likely to show visible clinical value (Sobhanian et al., 2022; Ball et al., 2021). Neurosurgeons in tertiary and teaching institutions are also among the most strategically placed users to evaluate the feasibility of adoption across clinical, organizational, and institutional levels. Their perceptions are representative of individual readiness and offer an early insight into diffusion potential more broadly.

Empirical evidence on how neurosurgeons in Indonesia perceive assistive robotic technologies remains limited. We do not know their levels of awareness, the specific barriers they identify, the key enablers they identify, or their overall willingness to adopt. Without this user-centered evidence, hospitals, policymakers, academic institutions and technology providers cannot sufficiently calibrate their investment and adoption strategies. No prior study has empirically mapped adoption readiness for this technology category among Indonesian specialist users.

This study therefore addresses that gap. Grounded in Rogers' (2003) Diffusion of Innovation (DoI) framework, it empirically assesses adoption readiness among 41 practicing neurosurgeons across Indonesia using a mixed-method design that integrates quantitative Likert-scale survey data with qualitative thematic analysis. A Readiness Index developed for this study, operationalized as the ratio of mean perceived enabler scores to mean perceived barrier scores, multiplied by 100, is introduced as a novel methodological instrument for profiling adoption readiness as a relational balance between facilitating and barrier perceptions.

Three research questions guide the study: (1) What are the levels of awareness, perceived barriers, and perceived enablers influencing the adoption of assistive robotic technologies in neurosurgery in Indonesia? (2) Which factors most strongly shape neurosurgeons' adoption readiness, including perceptions of institutional support? (3) What strategic pathways can accelerate adoption and support the development of a sustainable ecosystem in Indonesia?

The study makes three contributions. First, it provides empirical evidence on the user-side readiness landscape for an important but still understudied technology category in an emerging market context. Second, it introduces the Readiness Index as a methodological instrument for measuring adoption readiness as a proportional balance between supporting and limiting conditions. Third, it applies the DoI framework diagnostically, as a tool for identifying where a population stands on the diffusion curve before mainstream adoption has occurred, extending its conventional retrospective application to a prospective pre-adoption setting.

Literature Review

Assistive Robotic Technologies in Healthcare

Technological innovation in healthcare has shifted steadily toward precision-based and digitally integrated clinical systems. Advanced visualization platforms, robotic-guided instruments, AI-assisted navigation, and digital workflow tools are increasingly recognized not merely as instruments of technological advancement, but as practical enablers of more consistent, safe, and ergonomically sustainable surgical performance (Rivero-Moreno et al., 2023; WHO, 2023). In this context, assistive robotic technologies hold a distinctive role: they extend surgical capability but do not replace the surgeon’s direct judgment and control, making them more practically workable for healthcare systems still in the process of developing the infrastructure, training capacity, and institutional readiness necessary for fully autonomous robotic platforms.

The multi-layered challenge of implementing robotic-assisted surgical systems has been described by Lawrie et al. (2022) as a matter of dynamic financial, organizational, training-related and institutional barriers and enablers across different implementation phases. Technical availability of robotic surgical systems and individual user interest alone are insufficient drivers of adoption. Successful diffusion of robotic surgical systems is contingent on adequate financing structures, structured training pathways, ecosystem-level collaboration and sustained institutional support. This understanding of adoption as a systemic challenge informs the empirical design of the present study.

Technological Innovation in Neurosurgery

Neurosurgery has historically been an early adopter of precision-oriented surgical innovation. It is dependent on spatial accuracy, quality of intraoperative visualization, fine motor control and real-time anatomical decision making, making it receptive to technologies that improve consistency and reduce intraoperative variability (Sobhanian et al., 2022; Ball et al., 2021). Advanced neuronavigation systems, intraoperative imaging, robotic-guided planning and precision visualization platforms have become an integral part of contemporary neurosurgical practice, enhancing surgeons’ ability to navigate complex anatomical structures and perform minimally invasive procedures more safely (Singh et al., 2022; Stumpo et al., 2021).

Further, the ability for assistive robotic technologies to be integrated into existing operative environments supports their applicability to neurosurgery in emerging healthcare markets; assistive technologies are not necessarily scaled at the level of large-platform robotic systems, but can be adopted selectively at the level of a specialty, to be integrated gradually into established workflows. As such, neurosurgery represents a viable point of entry for structured adoption, particularly in Indonesia, where neurosurgical capacity is concentrated in tertiary and teaching hospitals with comparatively better infrastructure and access to specialist training (Kato et al., 2020; Wicaksono et al., 2020).

Diffusion of Innovation Framework

The theoretical basis of this study is based on Rogers' (2003) Diffusion of Innovation (DoI) theory. DoI conceptualizes the diffusion of innovations as a process where potential adopters go through a series of stages from awareness to persuasion, decision, implementation and confirmation. The rate and extent of diffusion are influenced by five perceived attributes of an innovation: relative advantage, compatibility, complexity, trialability and observability. Innovations that are perceived to be more useful, more compatible with existing practice, less complex, more testable and more visibly advantageous are likely to diffuse more rapidly.

DoI further categorizes adopters into innovators, early adopters, early majority, late majority, and laggards with differences in openness, evidence-dependence, and risk tolerance. Theoretically, the early majority forms about 34% of the adopting population. Its members tend to follow trusted peers once sufficient social proof and ecosystem maturity have accumulated, making them the point at which pioneer adoption transitions to mainstream diffusion. A very small share of this segment in a given population suggests that mainstream diffusion conditions have not yet been established.

The DoI was preferred over other frameworks such as the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) because it aims to explain the diffusion of innovations in social systems before the stage of mass adoption. TAM and UTAUT are better suited for settings where the technology is already available for direct evaluation by users. DoI is more appropriate for the pre-adoption, population-level and system-level focus of this study. Recent empirical work supports this choice. Chong et al. (2022) found that perceived usefulness, enabling conditions and environmental support strongly influence healthcare technology adoption, constructs consistent with DoI logic. Tustumi et al. (2025) and Maynou et al. (2022) further found that surgical robotics adoption is driven by perceived comparative advantage and visible outcome evidence, consistent with DoI's observability and relative advantage attributes.

Conceptual Framework

The conceptual framework of this study positions neurosurgeons' perceptions as the central analytical unit. Three empirical constructs, awareness, perceived barriers, and perceived enablers, are measured directly and then translated analytically into an adoption readiness profile through the Readiness Index and adopter segmentation. The readiness profile subsequently informs the identification of strategic pathways for adoption. This framework is grounded in the DoI principle that adoption is fundamentally a perception-driven process and that readiness should be understood as a relational balance between conditions that support and conditions that constrain adoption, rather than as a single-dimensional attitude.

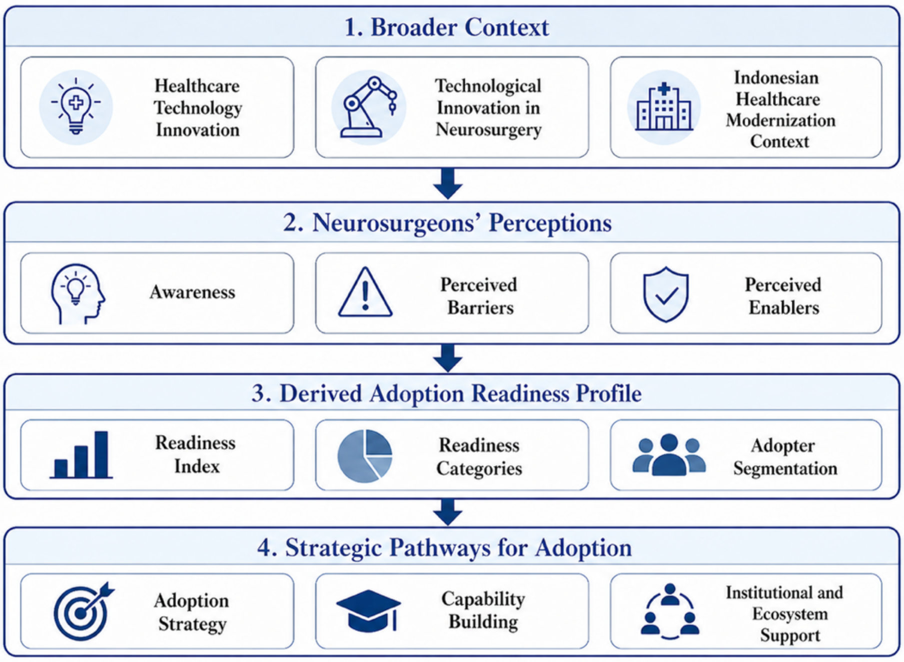

Figure 1
Conceptual Framework

Research Methodology
Research Design

This study employs a mixed-method exploratory research design, integrating quantitative Likert-scale survey data with qualitative thematic analysis. An exploratory orientation was selected because the adoption of assistive robotic technologies in Indonesian neurosurgery is still in a nascent stage, existing patterns of readiness, awareness, and institutional support have not yet been empirically mapped. A rigid explanatory design would be less suitable than an exploratory approach that allows the identification of patterns, emerging signals, and practical concerns from the field (Creswell & Creswell, 2018).

The quantitative component measures three constructs, awareness, perceived barriers, and perceived enablers, using structured Likert-scale items, producing numerical outputs including mean scores, reliability coefficients, a composite Readiness Index, readiness categories, and adopter segments. The qualitative component analyzes open-ended text responses from the same survey instrument, generating thematic codes that explain the reasoning and contextual logic behind the perception patterns measured quantitatively. The two strands are generated sequentially, quantitative first, qualitative second, and integrated in the final interpretive stage.

Sample and Data Collection

Data were collected from 41 practicing neurosurgeons across Indonesia, recruited through purposive sampling targeting active practitioners across hospital types and classifications. Table 1 summarizes the respondent profile.

Table 1
Respondent Profile

Variable	Category	Frequency	Percentage
Hospital Type	Government Hospital	29	70.7%
	Academic/Teaching Hospital	7	17.1%
	Private Hospital	5	12.2%
Hospital Class	Class A	25	61.0%
	Class B	14	34.1%
	Class C	2	4.9%
Years of Experience	< 5 years	20	48.8%
	5–10 years	11	26.8%
	11–20 years	8	19.5%
	> 20 years	2	4.9%
Robotic Acquisition Status	Already acquired	5	12.2%
	Planning to acquire	20	48.8%
	No current acquisition	13	31.7%
	Uncertain	3	7.3%

Measurement Instrument and Reliability

The survey instrument comprised three quantitative constructs measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree): Awareness (6 items), Perceived Barriers (7 items), and Perceived Enablers (6 items). Open-ended questions captured qualitative reasoning about barriers, support needs, recommendations, and the current state of implementation. Internal consistency was assessed using Cronbach's Alpha. All three constructs demonstrated very high reliability (Table 2), confirming the instrument's suitability for composite analysis.

Table 2
Reliability of Measurement Constructs

Construct	Items	Cronbach's α	95% CI
Awareness	6	0.933	0.874 – 0.993
Perceived Barriers	7	0.931	0.896 – 0.966
Perceived Enablers	6	0.927	0.878 – 0.976

The Readiness Index

A key methodological contribution of this study is the introduction of the Readiness Index (RI), a composite instrument developed for this study for measuring adoption readiness as a relational balance between enabling and barrier perceptions. The formula is:

Readiness Index = (Mean Enablers / Mean Barriers) × 100

This ratio formulation is grounded in the DoI principle that adoption readiness is not a single-dimensional attitude but a relational assessment of whether enabling conditions can balance or exceed constraining conditions. A score of 100 represents the equilibrium point, where barriers and enablers are perceived as equal in strength. A score above 100 indicates a net-facilitating perception environment; below 100 indicates net-constraining. The choice of a ratio over a simple difference score is deliberate: a difference score produces equivalent results for respondents with different absolute levels (e.g., Enablers = 4.5, Barriers = 4.0 and Enablers = 2.5, Barriers = 2.0 both yield +0.5), whereas the ratio captures proportional dominance and is more sensitive to the relative strength of each dimension (OECD, 2008; Sobhanian & Bate, 2022).

Respondents were categorized into three readiness levels: High Readiness (RI > 120, indicating enablers are at least 20% stronger than barriers), Medium Readiness (100 ≤ RI ≤ 120), and Low Readiness (RI < 100). The 120 threshold reflects the DoI logic that in high-capital, infrastructure-dependent technology contexts, a marginal enabler advantage is insufficient for meaningful adoption momentum. Adopter segmentation further classified respondents as Early Adopters (RI ≥ 120), Early Majority (110 ≤ RI < 120), Late Majority (100 ≤ RI < 110), and Laggards (RI < 100), consistent with Rogers' (2003) adopter categories.

Qualitative Analysis

Qualitative data from open-ended responses were analyzed using a five-step thematic procedure: (1) data organization and preparation; (2) open coding of recurring issue-level expressions; (3) axial coding into broader categories; (4) theme synthesis into higher-level patterns; and (5) integration with quantitative findings. This procedure followed established practice for qualitative analysis in mixed-method research (Patton, 2015; Guest et al., 2006).

Results and Discussion

Descriptive Results: Awareness, Barriers, and Enablers

Table 3 presents the descriptive statistics for the three main constructs. Neurosurgeons demonstrated a high level of awareness (mean 4.199), confirming broad familiarity with and recognition of the strategic and clinical relevance of assistive robotic technologies. Perceived enablers (mean 4.138) marginally outweighed perceived barriers (mean 3.920), indicating that the overall perception environment is net-facilitating, though the margin is modest and the barriers remain substantive.

Table 3
Descriptive Statistics of Main Constructs

Construct	Mean	Std. Deviation
Awareness	4.199	0.694
Perceived Barriers	3.920	0.807
Perceived Enablers	4.138	0.642

Barriers and Enablers: Item-Level Analysis

At the item level, financial barriers dominated the constraint landscape. The highest-rated barrier was initial investment cost (mean 4.171), closely followed by maintenance and consumables cost (mean 4.146). Unclear reimbursement or financing mechanisms (mean 3.951) and lack of trained personnel (mean 3.951) were the next most prominent constraints. Notably, the lowest-rated barriers, insufficient case volume (mean 3.610) and limited local technical support (mean 3.683), reflect practical implementation concerns rather than clinical skepticism about the technology's value. This pattern is analytically important: respondents do not fundamentally question the clinical case for adoption, but perceive a substantial financial and structural threshold.

On the enabler side, government support through public-private collaboration was the strongest enabler (mean 4.244), followed by structured local training programs to build confidence (mean 4.220), global partnerships with technology producers (mean 4.171), and the potential of robotic technology to strengthen Indonesia's medical tourism position (mean 4.171). Hospital management openness (mean 4.073) was viewed positively, and leasing schemes as affordability mechanisms, while the lowest-rated enabler, still scored 3.951, confirming that alternative financing models are viewed as viable pathways.

Table 4
Perceived Barriers by Item

Barrier Item	Mean	Std. Dev.
Initial investment cost too high	4.171	0.771
Maintenance and consumables costs	4.146	0.760
Lack of trained personnel	3.951	0.973
Unclear reimbursement / financing	3.951	0.921
Regulatory and import complexity	3.927	0.932
Limited local technical support	3.683	1.083
Insufficient case volume	3.610	1.202

Table 5
Perceived Enablers by Item

Enabler Item	Mean	Std. Dev.
Government support / public-private collaboration	4.244	0.663
Structured local training programs	4.220	0.690
Global partnerships with technology producers	4.171	0.704
Robotic technology for medical tourism	4.171	0.738
Hospital management openness to innovation	4.073	0.787
Leasing schemes for affordability	3.951	0.893

Readiness Index and Adopter Segmentation

The Readiness Index produced a sample mean of 108.5 (SD = 21.99; range 75.0–159.1), confirming that on average, enabling conditions are perceived to outweigh barriers, though with substantial individual variation. Readiness categorization revealed that 26.8% of respondents fell into the High Readiness category (RI > 120), 48.8% into Medium Readiness (100 ≤ RI ≤ 120), and 24.4% into Low Readiness (RI < 100). The majority of respondents therefore occupy a state of conditional readiness, aware and broadly supportive, but not yet positioned to move toward adoption without additional structural support (Table 6).

Table 6
Readiness Category of Respondents

Readiness Category	Threshold	Frequency	Percentage
High Readiness	RI > 120	11	26.8%
Medium Readiness	100 ≤ RI ≤ 120	20	48.8%
Low Readiness	RI < 100	10	24.4%
Total		**41**	**100%**

Adopter segmentation revealed 26.8% Early Adopters, 43.9% Late Majority, 24.4% Laggards, and only 4.9% Early Majority (Table 7). The very small Early Majority segment is the most theoretically significant finding of this study. In Rogers' (2003) DoI framework, the Early Majority is theoretically expected to constitute approximately 34% of the adopting population and serves as the structural bridge between pioneer adoption and mainstream diffusion. Its very small share, at only 4.9% compared to the expected 34%, signals that the social proof, ecosystem maturity, and institutional conditions required to activate this deliberate-adoption segment have not yet been established.

Table 7
Adopter Segmentation of Respondents

Adopter Category	RI Threshold	Frequency	Percentage
Early Adopter	RI ≥ 120	11	26.8%
Early Majority	110 ≤ RI < 120	2	4.9%
Late Majority	100 ≤ RI < 110	18	43.9%
Laggard	RI < 100	10	24.4%
Total		**41**	**100%**

Qualitative Thematic Findings

Thematic analysis of open-ended responses produced five dominant themes (Table 8). Financial barriers were the most prominent theme, mentioned by 34 respondents (82.9%). Respondents described investment burden, maintenance costs, and the constraints of the national health insurance (BPJS) reimbursement framework as the clearest practical obstacles. Capability building needs were cited by 33 respondents (80.5%), with recurring calls for structured training, product demonstrations, workshops, and hands-on exposure, suggesting that training is viewed not as supplementary but as a necessary precondition for adoption.

Technical and operational readiness concerns were equally prominent (80.5%), with respondents describing the current implementation environment using terms such as belum matang (not yet mature) and masih berjalan merangkak (still moving slowly). Policy and ecosystem support was cited by 18 respondents (43.9%), emphasizing the perceived role of government policy, subsidies, and multi-stakeholder coordination. Evidence and adoption justification was a minority theme (9.8%), pointing to a smaller but strategically relevant segment that requires stronger clinical proof before supporting broader implementation.

Table 8
Dominant Qualitative Themes from Open-Ended Responses

Theme	Respondents (n)	Percentage	Interpretation
Financial Barriers	34	82.9%	Most dominant; cost and affordability as the primary practical obstacle
Capability Building Needs	33	80.5%	Training and exposure as a necessary prerequisite, not a supplement
Technical & Operational Readiness	33	80.5%	Implementation environment perceived as still immature
Policy & Ecosystem Support	18	43.9%	Government and multi-stakeholder coordination seen as critical enabler
Evidence & Adoption Justification	4	9.8%	Smaller but relevant segment requiring clinical proof before committing

Strategic Outlook: Priority Specialty and Action Priorities

Strategic perception items further reinforced the case for a neurosurgery-first approach. When asked which specialty should be prioritized for early adoption, 90.2% of respondents (37 of 41) identified neurosurgery, with only two respondents each selecting urology and general surgery. On the question of mainstream adoption timing, 61.0% projected more than five years, and 26.8% indicated three to five years, confirming that respondents view this as a long-term process requiring sustained structural investment rather than near-term market readiness.

Weighted ranking of strategic action priorities produced a clear ordering: (1) training and capability building, (2) hybrid financing mechanisms, (3) regulatory pathway clarification, (4) clinical evidence development, and (5) institutional partnership. This hierarchy directly maps the pathway from awareness to action: respondents prioritize capability confidence before financial accessibility, and both before policy and evidence infrastructure.

Discussion

The integrated findings reveal an adoption landscape characterized by high awareness and conditional openness, constrained principally by financial and structural barriers rather than by clinical skepticism. The Readiness Index mean of 108.5 confirms a net-enabling perception environment at the aggregate level, but the substantial variance (SD = 21.99) and the uneven adopter distribution underscore that this enabling advantage is neither uniform nor sufficient to activate mainstream diffusion.

The most important analytical finding, the Early Majority gap at 4.9% versus the theoretically expected 34%, extends the DoI framework in an important direction. Previous applications of DoI in healthcare technology adoption have primarily described completed or ongoing diffusion processes (Chong et al., 2022; Maynou et al., 2022). This study applies DoI prospectively and diagnostically: the adopter segment distribution is used not to describe where adoption has arrived, but to identify precisely where it is structurally blocked. The very small Early Majority segment is not a measurement anomaly but a theoretically coherent signal that the social proof, visible reference effects, and ecosystem conditions that activate deliberate adopters have not yet been established in Indonesian neurosurgical practice.

This finding also clarifies the nature of the principal challenge. The primary barrier is not user cognition or clinical rejection; awareness is already high and most respondents are broadly supportive. The barrier resides at the level of financial architecture, institutional capacity, and ecosystem infrastructure. This conclusion is consistent with Lawrie et al. (2022), who argue that robotic surgery adoption is fundamentally shaped by multi-layered systemic conditions rather than individual user attitudes, and with Sobhanian and Bate (2022), who emphasize that healthcare automation readiness must be evaluated through the joint assessment of facilitating and constraining conditions.

The Readiness Index introduced in this study offers a methodological contribution to this literature. By operationalizing readiness as a proportional ratio rather than a difference score or single-dimensional scale, it captures the relative dominance of enabling over barrier perceptions, a distinction that is theoretically meaningful within the DoI framework and practically useful for profiling heterogeneous adopter populations in pre-adoption settings (OECD, 2008).

From a managerial perspective, the findings carry direct implications for three stakeholder groups. For hospital management, the results indicate that adoption should be framed as a staged organizational commitment rather than a single procurement decision, beginning with internal readiness assessment and Early Adopter identification before any capital planning. For policymakers, the dominant role of financial barriers and the high priority placed on government support through public-private collaboration point toward the urgency of developing clearer reimbursement frameworks and structured financing schemes. For technology providers, the high training priority suggests that market entry strategies focused exclusively on equipment positioning will be insufficient; investments in local training infrastructure and flexible financing models are necessary preconditions for sustainable adoption.

The study has several limitations. Its scope is limited to neurosurgeons' perceptions and does not include independent measurement from hospital management or procurement decision-makers. The cross-sectional design captures a single point in time and cannot track changes in readiness over time. The sample is concentrated in tertiary and teaching hospitals, which may overrepresent more favorably positioned institutions compared to the broader Indonesian healthcare system. Future research should extend the readiness assessment to multi-stakeholder perspectives, replicate the design across other surgical specialties, and conduct longitudinal follow-up studies to test whether the proposed strategic pathways produce measurable shifts in readiness and adopter distribution.

Conclusion

This study provides the first systematic empirical assessment of adoption readiness for assistive robotic technologies among neurosurgeons in Indonesia. Three principal conclusions emerge.

First, Indonesian neurosurgeons demonstrate high awareness of assistive robotic technologies (mean 4.199) and conditionally favorable perceptions, with enabling conditions marginally outweighing barriers at the aggregate level. The primary obstacles are financial, initial investment cost and maintenance, rather than conceptual or clinical. This confirms that the central challenge is not persuasion but pathway construction: the conversion of existing awareness and interest into operationally feasible and financially sustainable adoption.

Second, the Readiness Index analysis, producing a sample mean of 108.5 with 48.8% Medium Readiness and 24.4% Low Readiness, reveals a predominantly conditional readiness profile. The adopter segmentation finding of only 4.9% Early Majority against an expected 34% is the most theoretically significant result: it signals that the social proof, reference centers, and ecosystem maturity required to activate mainstream diffusion have not yet been established. Adoption is championed by an Early Adopter minority but has not yet generated sufficient momentum to cross the diffusion threshold into broad uptake.

Third, four evidence-based strategic pathways are proposed: (1) a neuro-first adoption strategy, positioning neurosurgery as the structured entry point given clinical relevance and the concentration of Early Adopters; (2) structured capability-building programs including local workshops, technology demonstrations, simulation access, and peer reference networks; (3) hybrid financing models comprising leasing, shared-use arrangements, and public-private partnership frameworks that lower the financial entry threshold; and (4) multi-stakeholder ecosystem coordination across hospitals, policymakers, professional associations, and technology providers to build the regulatory, reimbursement, and partnership infrastructure for sustainable diffusion.

The study makes three theoretical contributions. It extends the DoI framework as a prospective diagnostic tool for pre-adoption settings, demonstrating that adopter segmentation can identify structural diffusion gaps before mainstream adoption has occurred. It introduces the Readiness Index as a novel methodological instrument for measuring adoption readiness as a relational balance, applicable to future adoption readiness studies across technology categories and healthcare contexts. And it provides empirical evidence that in emerging healthcare markets, the principal barrier to advanced technology adoption resides not at the level of user cognition but at the level of financial architecture, institutional capacity, and policy infrastructure.

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