

Measuring Timeliness and Speed of Policy Implementation: Evidence from the Hainan Digital Therapeutics Policy Package

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Abstract

Background

The timeliness and speed of implementation have rarely been measured directly, and policy research seldom treats timeliness as a measurable outcome. This study measures the timeliness, speed, and determinants of policy implementation speed, using the Hainan digital therapeutics (DTx) policy package.

Methods

We used an observational embedded single-case study design, treating the Hainan DTx policy package of 21 measures as an implementation object. Guided by Howlett's policy cycle model, the Framework to Assess Speed of Translation (FAST), and Diffusion of Innovations (DOI) theory, we applied directed content analysis to publicly available provincial policy documents and gray literature from January 2022 to October 2025. Independent dual coding with consensus procedures was applied to phase identification, timeliness assessment, and coding of implementation speed determinants. A deadline-anchored rubric classified each measure's timeliness as strong, moderate, or weak. Determinants of speed were rated from - 2 to + 2 across the FAST domains.

Results

The DTx policy package evolved through four lifecycle phases from agenda-setting and policy design to active implementation and early sustainment, with active policy measure categories expanding from two to five to six and consolidating to four. Sixteen of 21 measures (76%) translated into dedicated follow-up actions on time during active implementation; policy implementation accelerators were mostly persistent, whereas decelerators were mixed: four decelerators were persistent (complexity, financial resources, lagged readiness, and lagged systemic connectivity), while the rest were transient and phase-specific. The cumulative trajectory of major policy actions formed the inverse of the canonical DOI S-curve.

Conclusions

Policy implementation timeliness serves as a diagnostic signal of where further policy action is needed, and the deadline-anchored rubric offers a transferable tool for its measurement. Policy implementation speed reveals the implementation process shaped by persistent or phase-specific accelerating and decelerating determinants and may follow a temporal trajectory inverse to the canonical DOI S-curve.

Introduction

The slow translation of evidence and innovation into routine practice has long defined implementation science. The frequently cited estimate that evidence-based practices take approximately 17 years to achieve widespread use has fueled sustained calls to accelerate implementation (1, 2). Yet, while substantial attention has been devoted to *what* should be implemented, *how* to implement it, and *for whom*, the *when* of implementation (speed, tempo, and timeliness) remains strikingly underexamined (3, 4). In the policy domain, this gap is especially pronounced: policy is widely recognized as a powerful lever for shaping implementation at scale, yet policy research has rarely treated timeliness as a measurable outcome. When policy actions occur, how policy implementation evolves in pace and direction (or scope) over time, how well the pace and direction match what was intended, and where progress accelerates or stalls are questions that remain largely unanswered.

This study explores the timeliness and speed of policy implementation using the case of a medical digital therapeutics (DTx) policy in Hainan, China. The Hainan DTx policy package launched in September 2022. The package comprised 21 policy measures, each carrying a predefined implementation deadline. DTx are evidence-based, government-regulated software medical devices whose translation into practice depends on coordinated policies and programs across multiple domains,

including regulation, clinical research, service delivery, financing, data governance, and market development (5, 6). Because these domains are governed by different institutions and actors, policy implementation typically involves multiple interdependent measures enacted in sequence or in parallel (7). This structure creates meaningful variation in implementation timing, making timeliness both analytically feasible and substantively important. The DTx policy package provides an analytically informative setting for examining policy timeliness in the implementation of DTx policy in Hainan. We document the speed of moving through various phases of the policy implementation, compare the expected and observed speeds of movement through those phases, and explore factors that affect the speed of adoption.

Several theoretical frameworks provide tools to address this gap (8). Diffusion of Innovations (DOI) theory embedded time as a core dimension, shaping the innovation-decision process (knowledge, persuasion, decision, implementation, confirmation), adopter categorization (innovators, early adopters, early majority, late majority, laggards), and the S-shaped cumulative adoption curve (9–12). The Framework to Assess Speed of Translation (FAST) extended this line of work by specifying measurable referents, endpoints, and determinant domains (innovation, adopter, context) for studying implementation speed (3). The Designing for Accelerated Translation (DART) framework further emphasized that implementation speed should respond dynamically to evolving evidence on effectiveness, demand, and risk (13). A small but growing body of empirical work has begun to reveal the temporal texture of policy implementation (14). Moran et al. (2020) documented how HIV treatment scale-up across sub-Saharan Africa proceeded in bursts, with rapid expansion phases alternating with institutional bottlenecks (15). During COVID-19, La et al. (2020) showed that national therapeutic diffusion timelines diverged sharply even among countries with comparable regulatory capacity (16), while Morais (2024) found that pandemic response measures advanced at markedly different speeds across governance levels within the same jurisdiction (17). Kumwenda et al. (2021) traced ART policy implementation across multiple countries and identified coordination failures between national and district-level actors as a primary source of temporal friction (18). These studies demonstrate that policy processes advance unevenly, with periods of rapid movement followed by delay or reconfiguration, and that this unevenness is shaped not only by political commitment but also by coordination demands and multi-level governance dynamics. However, no study has systematically operationalized timeliness as a quantifiable policy outcome, and empirical examination of coordinated technology policy implementation speed is virtually absent (19, 20).

This study treats the Hainan DTx policy package as an implementation object and examines policy timeliness as a service outcome (i.e., a service system outcome at the policy level). This study aims to address three research questions: (1) How did the Hainan DTx policy evolve across lifecycle phases, and what major policy actions characterized each phase? (2) To what extent were the 21 policy measures translated into observable follow-up actions, and how timely was this translation relative to predefined deadlines? (3) What factors were associated with accelerated or decelerated progress across phases, drawing on FAST's innovation, adopter, and contextual determinant domains? Using an observational design with directed content analysis of publicly available policy documents (January 2022–November 2025), this study responds to calls for data-based research on policy timeliness and offers methodological and substantive insights into how complex digital health policies unfold in practice.

Methods

Study design and guiding frameworks

This study employed an observational embedded single-case study design (21, 22), treating the Hainan digital therapeutics (DTx) policy package as an implementation object (23, 24). Three frameworks structured the inquiry: the Howlett's policy cycle model demarcated phases of policy evolution (25), from which we merged policy formulation and decision-making into a single design phase due to the Hainan DTx policy case context; the Framework to Assess Speed of Translation supplied the determinant taxonomy (innovation features, adopter characteristics, features of context) (26); and Diffusion of Innovations theory provided the idealized S-curve for comparison with the observed trajectory (9).

Three constructs were defined. Speed has two dimensions: pace, the rate at which major policy actions accumulate, and direction, the changing scope of policy actions across phases. Timeliness is speed evaluated against a benchmark: how well

the realized pace and direction match what the policy intended. Determinants of speed are the accelerating and decelerating factors shaping pace and direction. Because timeliness is the benchmark-referenced expression of speed, the same determinants of speed explain why some measures were timely and others were not.

Data Collection

The evidence base was collected in two rounds in Jan 2024 and Jan 2026, and comprised a publicly available documentary database from January 2022 to October 2025 (Supplementary File 1). The primary source consisted of 17 provincial policy documents, including the DTx section in the initial digital health reform plan, DTx-specific regulatory and implementation plans, and the later DTx high-quality development guidance, retrieved through systematic search of the Hainan provincial government information-disclosure system and websites of all agencies named in the master policy document (see full translation in Supplementary File 2), using search terms derived from the 21 DTx measures. The secondary source comprised 34 gray literature: government-issued digital-health blue papers, agency press releases, and official communications via institutional WeChat channels, which were collected to capture implementation activities outside formal policy instruments (27). All materials were managed in NVivo (28).

Data analysis

All coding followed directed content analysis (29), with priori constructs drawn from the guiding frameworks (9, 25, 26), supplemented by inductive identification of themes. A four-member coding team conducted the analysis following protocol training. Independent dual coding with consensus reconciliation was applied to all analyses (30). This study analyzed exclusively publicly available government documents and involved no human subjects. We followed the Standards for Reporting Qualitative Research reporting guideline to collect and report data (31) (Supplementary File 3). A larger DTx policy evaluation research project received ethical approval from the Peking University Institutional Review Board (IRB00001052-25202), and was conducted in accordance with the Declaration of Helsinki (32).

Phase classification (RQ1)

Two coders (WL and ZW) coded and assigned each policy document to one of four a priori lifecycle phases (origin, design, active implementation, and early sustainment). The origin phase captured agenda-setting and feasibility exploration of DTx in the broader digital health reform agenda before DTx-binding regulatory instruments were introduced. The design phase encompassed multi-stakeholder consultation and policy development, informed by rapid workshops and community stakeholder input. The active implementation phase was demarcated by the enactment of the twenty-one measures, defined measure deadlines, and coordination mechanisms. DTx policy timeliness was assessed only during this phase. The early sustainment phase reflected institutional embedding and system consolidation, marked by the completion of the three-year implementation period for the twenty-one measures. Assignment was governed by each document's dominant policy function. Within each phase, policy characteristics were mapped to their topic, timing (or temporal window), implementation setting, lead entities, and participating organizations, drawing on the five-step methodology for characterizing policy actors (33, 34).

Timeliness assessment (RQ2)

The twenty-one measures constituted the coding units. At the measure level, the policy's predefined deadline served as the benchmark. For each, we extracted its deadline, action domain, and responsible organizations; for each subsequent operational document, we recorded the linked measure(s), issuing agency, release date, and whether it explicitly named DTx as its regulatory object. Timeliness was operationalized through a criterion-based rubric combining two dimensions: whether a subsequent operational action was issued before the measure's deadline (or by August 2025, the end of the three-year implementation period, for long-term measures), and whether that action was a dedicated, DTx-specific instrument rather than subsumed within a broader policy. Each measure was classified as *strong* (dedicated DTx-specific action within the deadline

window), *moderate* (DTx addressed within a broader policy, within the window), or *weak* (no qualifying action issued). The rubric was developed by the first author and refined through team discussion; two coders (XX and ZW) independently applied it to all twenty-one measures, and discrepancies were resolved through deliberated consensus.

Determinant coding (RQ3)

Factors affecting speed were identified through directed coding of the full documentary corpus against the three FAST determinant domains (26). Within each phase, passages evidencing facilitating or impeding influences were assigned a directional intensity rating on a - 2 (strong decelerator) to + 2 (strong accelerator) ordinal scale, following the determinant construct rating convention (35). Every rating was anchored to a verbatim documentary excerpt retained in an audit trail (Supplementary File 4). Two coders (YK and ZW) independently identified, coded, and rated determinants, reconciling disagreements through consensus.

To model the progression of the policy package through its lifecycle (Origin, Design, Active Implementation, and Early Sustainment), bridging the gap between qualitative factors and observable policy speed, we transformed these qualitative ratings into three core metrics: acceleration, the number of speed determinant themes, and phase-standardized acceleration (adjusted for phase-specific accelerator counts).

1. Acceleration (a): Within each lifecycle phase, acceleration (a) is defined as the sum of all rating scores assigned to the speed determinant themes identified in that phase: $a = \sum_{i=1}^N \text{Score}_i$. This metric represents the net force (positive or negative) exerted by the accelerators and decelerators within a specific phase.
2. Number (N) and mean number ($\bar{N}$):
3. $\bar{N}$ (Phase Count): This refers to the total number of speed determinant themes identified within a specific phase, serving as a proxy for the thematic complexity or the volume of active drivers and barriers present.
4. $\bar{N}$ (Lifecycle Average): This is the mean number of speed determinant themes calculated across all four phases of the lifecycle ($\bar{N} = \frac{\sum N}{4}$). It establishes a baseline for the average thematic activity of the entire policy process.
5. Phase-standardized Acceleration (a_s): To capture the effective force that determines policy speed, we calculated the phase-standardized acceleration (a_s). This metric adjusts the raw cumulative acceleration by the relative thematic density of the phase: $a_s = a \times \left(\frac{\bar{N}}{N} \right)$. By scaling the sum of scores (a) by the ratio of the average number of themes across lifecycle phases to the number of themes in a given phase ($\bar{N} / N$), we account for how the volume of determinants of speed impacts the intensity of progress. This adjustment reduces the inflationary effect of high thematic density.

Results

The Hainan DTx policy cycle and characteristics

The Hainan DTx policy package evolved through four interrelated lifecycle phases, policy origin, policy design, active implementation, and early sustainment (Fig. 1; Table 1). Figure 1 illustrates the continuity and change in active policy measure categories across phases, tracing which policy categories were introduced, carried forward, or discontinued over time. Table 1 specifies the operational characteristics of each phase, including policy topics, timing, implementation settings, lead entities, and participating organizations.

The policy origin phase (early January 2022) marked the formal recognition of DTx as a legitimate policy issue and as a use case within Hainan's digital-health reform agenda. Two measure categories were active, namely implementation and dissemination, led by the provincial health commission through short-term drafting working groups, with the phase centered on vision-setting and agenda alignment (Table 1).

The policy design phase (March 2022) translated this aligned vision into a coherent policy architecture. Through a sequence of multi-stakeholder workshops, the active categories expanded to five: dissemination, trial, approval, standardization, and financing. Table 1 shows that each policy category was associated with a specific policy topic and participating entities, including overseas DTx enterprises, healthcare institutions, health administrative agencies, regulatory authorities, and software-related stakeholders. The phase extended the policy from market education and use facilitation of DTx only, to multi-domain alignment across health, regulatory, data-governance, and financing systems.

The active implementation phase (October 2022) reflected the operationalization of the DTx policy package of 21 measures. The package included six measure categories, including trial, approval, implementation, financing, dissemination, and standardization. A clear temporal sequencing was observable (Table 1): implementation and dissemination activities began early to stimulate DTx uptake; trial and approval related activities followed to formalize evidence generation and market entry; and financing measures carried longer horizons tied to accumulated implementation experience. This was the most institutionally complex phase, with implementation, dissemination, trial, approval, standardization, and financing activities distributed across multiple venues, including hospital meetings, medical consortium coordination meetings, training sessions, project selection events, regulatory consultations, data-governance reviews, and financing deliberations. This phase transformed the policy package from a design blueprint into a set of time-bound and institution-specific implementation tasks, allowing subsequent assessment of policy timeliness (Section 4.2).

The early sustainment phase (from October 2025) centered on institutionalization, anchored in a new guiding policy document and the switching to a regulatory-focused lead agency. Three policy measure categories, including implementation, dissemination, and financing, were discontinued; trial, approval, and standardization were retained; and a new globalization category emerged. Table 1 shows that the leading role shifted toward the provincial medical products administration for approval, standardization, and globalization-related activities, while the provincial health commission remained involved in real-world evidence generation. This transition suggests that the policy package moved from early uptake and ecosystem-building toward a more regulatory and internationally oriented sustainment agenda.

Table 1
Modified Five-step methodology for identifying the DTx policy characteristics

What policy		When	Where	What and who		
Phase	category	Topics	Start date (Duration)	"Room"	Leading entities	Participating entities
Origin	Implementation	Scale up digital therapeutics to improve population health management	Early January 2022 (One month)	Policy drafting working group	Provincial health commission	• Healthcare institutions • Medical administration bureaus
	Dissemination	Strengthen digital therapeutics dissemination, investment, and innovation ecosystems	Early January 2022 (One month)	Policy drafting working group	Provincial health commission	• Healthcare institutions • Medical administration bureaus
Design	Dissemination	Support market entry and local establishment of overseas digital therapeutics enterprises	22 March 2022 (Half day)	Online multi-stakeholder policy workshop	Provincial health commission	• Provincial development and reform commission • Provincial department of commerce • International DTx enterprises
	Trial	Pilot institution-based clinical trials of digital therapeutics within healthcare settings	22 March 2022 (Half day)	In-person stakeholder workshop	Provincial health commission	• DTx enterprises • Healthcare institutions
	Approval	Establish expedited regulatory review pathways for software-based digital therapeutics	23 March 2022 (Half day)	In-person stakeholder workshop	Provincial health commission	• Provincial medical products administration • Provincial software community • DTx enterprises
	Standardization	Strengthen data governance and cybersecurity standards for digital therapeutics	23 March 2022 (Half day)	In-person stakeholder workshop	Provincial health commission	• Provincial big data administration • Provincial cyberspeed administration • DTx enterprises
	Financing	Integrate digital	24 March 2022	In-person stakeholder	Provincial health commission	• Provincial healthcare

What policy			When	Where	What and who	
		therapeutics into public health insurance and commercial insurance payment mechanisms	(Half day)	workshop		security administration • Provincial banking and insurance regulatory bureau • DTx enterprises
Active Implementation	Implementation	Promote Application of DTx Products	11 October 2022 (3 months)	Hospital executive board meetings	Hospital presidents or vice presidents	• Healthcare professionals
				Medical consortium coordination meetings	Municipal/county health commissions	• Healthcare professionals • IT service providers
				In-hospital training sessions	Hospital teaching department	• Healthcare professionals • DTx enterprise
	Dissemination	Strengthen Awareness and Industry Cluster Development	11 October 2022 (3 months)	Piloting project selection meetings and launch events	Provincial health commission; Provincial department of industry and information technology	• Healthcare institutions • DTx enterprises • Local governments • Media
						• Investment institutions • Research organizations • Industry associations
						• Healthcare professionals • Patient representatives
	Trial	Build a Nationally Leading Digital Therapeutics Clinical and Research Demonstration Base	11 October 2022 (3 months)	Hospital Institutional Review Board (IRB) meetings	Hospital IRB chairs	• Healthcare professionals • Patient representatives
				Industry standard-setting workshops	Medical societies or industry associations	• Healthcare institutions • Research organizations • DTx enterprises
	Approval	Accelerate Registration and Approval of DTx Products	11 October 2022 (Long-term)	Expedited medical device technical review processes	Provincial medical products administration	• Research organizations • DTx enterprises

What policy		When	Where	What and who	
			Product classification expert consultation meetings	Provincial medical products administration	Y Research organizations Y DTx enterprises
			Real-world evidence project review panels	Provincial medical products administration	Y Research organizations Y DTx enterprises
			Data security compliance assessment meetings	Provincial cyberspeed administration	Y Research organizations Y DTx enterprises Y Industry associations
			Cross-border data security assessment meetings	Provincial data security authorities	Y Research organizations Y DTx enterprises Y Industry associations
	Financing	11 October 2022 (40 months)	Fiscal special fund project review meetings	Provincial department of finance	Y Provincial health commission Y DTx enterprises
			Science and technology project review meetings	Provincial department of science and technology	Y Industry association Y Research institutions Y DTx enterprises
			Health insurance coverage deliberation meetings	Provincial healthcare security administration	Y Industry association Y Research institutions Y Healthcare institutions
			Health insurance–commercial insurance coordination roundtables	Provincial healthcare security administration	Y Healthcare institutions Y Commercial insurers Y DTx enterprises

What policy			When	Where	What and who	
Sustainment Phase	Trial	Encourage real-world evidence generation for digital therapeutics	29 October 2025 (Long-term)	RWE project initiation and rolling review panels	Provincial health commission	• Provincial medical products administration • Healthcare institutions • Research institutions • DTx enterprises
	Approval	Accelerate digital therapeutics translation, registration, and market entry	29 October 2025 (Long-term)	DTx product translation and registration coordination meetings	Provincial medical products administration	• Provincial Health Commission • DTx enterprises
	Standardization	Establish robust, safe, and effective digital therapeutics regulatory oversight	29 October 2025 (Long-term)	Digital therapeutics regulatory joint meetings	Provincial medical products administration	• Provincial health commission • Provincial cybersspeed administration • Provincial bureau of big data
				Post-launch risk monitoring and re-evaluation meetings	Provincial medical products administration	• Healthcare institutions • DTx enterprises
	Globalization	Expand international collaboration and openness in the digital therapeutics industry	29 October 2025 (Long-term)	International digital therapeutics cooperation and market access coordination meetings	Provincial medical products administration	• Provincial department of commerce • Research institutions • Industry associations • International DTx enterprises

Timeliness of policy translation during active implementation

Each DTx policy measure carried a predefined deadline, which we used to evaluate whether and how quickly the measure was followed by concrete policy action (Table 2) and classify categorically as strong, moderate, or weak in timeliness. Sixteen of 21 measures (76%) were classified as strong in timeliness. Three measures (14%), including “exploring DTx product notification system and promoting real-world data (RWD) use”, “integrating DTx into healthcare payment reforms”, and “enhancing data security and utilization”, showed moderate timeliness. Among these measures, DTx-related content was incorporated into broader emerging medical device policies rather than addressed through dedicated subsequent policies and programs. Two measures, “promoting integration of DTx with Internet hospitals” and “using Free Trade Port investment funds to support DTx through equity financing”, were classified as weak (10%), reflecting no immediate motivation for dedicated policy introduction.

Timeliness varied by domain. Administrative measures, such as establishing clinical-trial centers, issuing regulatory guidance, and building dissemination platforms, advanced rapidly. Financial and data-governance measures, payment-reform integration, equity financing, and real-world data mechanisms, advanced more slowly.

Table 2

The “Twenty-One Measure” Hainan DTx policy and the timeliness of each policy measure by structured category

Category	Policy Measure	Deadline	Strong	Moderate	Weak
Regulatory Pathway					
Build a Nationally Leading Digital Therapeutics Clinical and Research Demonstration Base (Trial)	(1) Establish digital therapeutics clinical trial centers	Oct 31, 2022	✓		
	(2) Promote R&D and clinical translation of DTx	Dec 31, 2022	✓		
	(3) Develop public service and management platforms for DTx	Oct 31, 2022	✓		
Accelerate Registration and Approval of DTx Products (Approval)	(4) Issue classification and regulatory guidance documents	Dec 31, 2022	✓		
	(5) Establish dedicated consultation channels for Class II medical DTx product registration	Oct 31, 2022	✓		
	(6) Develop a DTx Encouraged Products Directory and fast-track approval channel	Oct 31, 2022	✓		
	(7) Explore DTx product notification system and promote real-world data (RWD) use	Long-term		✓	
Real-World Application					
Promote Application of DTx Products (Implementation)	(8) Establish DTx application bases in medical institutions	Dec 31, 2022	✓		
	(9) Promote integration of DTx with Internet hospitals	Dec 31, 2022			✓
	(10) Establish national demonstration zones for DTx applications	Dec 31, 2022	✓		
	(11) Encourage broader societal use of DTx	Dec 31, 2022	✓		
Encourage Diverse Payment Mechanisms (Financing)	(12) Explore integration of DTx with commercial insurance	Dec 31, 2025	✓		
	(13) Include DTx in service pricing and medical insurance coverage	Dec 31, 2022	✓		
	(14) Integrate DTx into healthcare payment reforms	Dec 31, 2022		✓	

Note. The timeliness of policy measure was categorized as **strong** (established dedicated digital therapeutics policies in time), **moderate** (digital therapeutics included in a broader policy or inexplicitly included in a related policy in time), or **weak** (no immediate need for a dedicated policy before deadline or till now, despite measure-related activities may be ongoing). The classification of timeliness is strong, moderate, or weak depending on whether it had subsequent operational policy documents issued before the deadline as predefined in the master policy document or till now, and, if so, whether those documents were concrete and DTx-specific. Full translation sees Supplementary File 2.

Category	Policy Measure	Deadline	Strong	Moderate	Weak
Ecosystem Cultivation					
Strengthen Awareness and Industry Cluster Development (Dissemination)	(15) Build high-quality DTx industrial clusters	Dec 31, 2023	✓		
	(16) Attract overseas DT enterprise	Dec 31, 2022	✓		
	(17) Build Hainan's DTx Innovation Island Bran	Dec 31, 2022	✓		
Promote Standardized Development and Supporting Measures (Standardization)	(18) Establish DTx Standards and Associations	Dec 31, 2022	✓		
	(19) Enhance data security and utilization	Dec 31, 2022		✓	
	(20) Strengthen DTx Talent Development	Dec 31, 2022	✓		
	(21) Use Free Trade Port investment funds to support DTx through equity financing	Dec 31, 2022			✓
Note. The timeliness of policy measure was categorized as strong (established dedicated digital therapeutics policies in time), moderate (digital therapeutics included in a broader policy or inexplicitly included in a related policy in time), or weak (no immediate need for a dedicated policy before deadline or till now, despite measure-related activities may be ongoing). The classification of timeliness is strong, moderate, or weak depending on whether it had subsequent operational policy documents issued before the deadline as predefined in the master policy document or till now, and, if so, whether those documents were concrete and DTx-specific. Full translation sees Supplementary File 2.					

Factors associated with accelerated or decelerated progress

Sixteen determinant themes were identified across the four phases and organized into three domains, including features of the innovation, adopter characteristics, and features of context (Fig. 2). Eight themes operated predominantly as accelerators and eight as decelerators. Detailed descriptions and quotes of each determinant are presented in the Supplementary File 4.

Features of the innovation

Relative advantage justified the prioritization of DTx policy across all phases. In the origin and design phases, this was framed as the strategic potential of DTx to address unmet clinical needs. By the implementation and sustainment phases, positive clinical validation reduced institutional uncertainty and triggered higher-level fiscal and institutional support. Compatibility with Hainan's established Internet-healthcare infrastructure supplied an early strategic fit. During active implementation, this compatibility evolved into a functional fit, as DTx enabled Internet hospitals to expand from prescription-based services toward software-supported care delivery. In the sustainment phase, continued alignment with emerging digital health priorities, including agentic artificial intelligence, helped keep the policy current.

Complexity of the DTx policy package acted as a persistent decelerator across the lifecycle. In the origin and design phases, it manifested as data-interoperability gaps and absent standardized regulatory pathways; in later phases, the bottleneck shifted toward immature commercial models and payment policy gaps. Lacking observability emerged as a decelerator during implementation, where feedback delays kept the intervention's value less visible to clinical users.

Adopter characteristics

Organizational openness accelerated policy finalization through active consultation: government surveys and workshops involving external experts and enterprises reduced information asymmetry in early phases, while public service platforms and industry forums maintained responsiveness to stakeholder input in later phases. Leadership accelerated progress from the design phase onward through binding deadlines and goal-driven accountability. A service-oriented governmental posture further reduced bureaucratic friction during implementation and sustainment, through fast-track registration channels, dedicated regulatory assistance, and industry-specific guidance.

Lagged systemic connectivity imposed a persistent coordination time-lag from design through sustainment, as DTx policy required horizontal integration across health commissions, regulatory bodies, and private enterprises. Lagged acceptance emerged during implementation, where a knowledge gap among medical professionals, including limited specialist engagement and insufficient clinical trust among primary care physicians, slowed diffusion. Adopter affordability acted as a decelerator in the sustainment phase: high out-of-pocket costs slowed adoption, leaving progress contingent on government willingness and capacity to subsidize DTx use.

Features of context

Political pull generated top-down urgency across all phases through alignment with national innovation goals and provincial health targets, legitimizing DTx as a priority and motivating expedited administrative responses. Institutional advantage, including specialized regulatory mandates and regional innovation authorities, enabled adaptive, expedited market-access pathways. A pre-existing industrial base, comprising digital infrastructure and medical and information industry clusters, lowered entry barriers and reduced start-up costs.

Financial resources constraint persisted as a decelerator across phases: in origin and design, this manifested as absent coordinated funding mechanisms and challenges in securing large-scale fiscal appropriations; in implementation and sustainment, the investment requirements for R&D grants and industry funds slowed progress. Lagged readiness reflected a foundational gap: the absence of integrated platforms and specialized DTx experts in early phases required significant time before effective policy design was possible, and unsettled payment frameworks and data-standardization gaps continued to delay full operationalization into later phases. Uncontrollable events, notably pandemic disruption, introduced unavoidable delays during implementation.

According to Supplementary File 4, we summarized the -2 to $+2$ ratings with three phase-level metrics: raw acceleration (a), the sum of all ratings; N , the number of active speed determinant themes; and phase-standardized acceleration (a_s), where (N) = 11.75 is the mean theme count across four phases.

The net score of influences was biggest in the design phase and smallest in active implementation. Specifically, the design phase posted the highest a_s at 10.58 ($a = 9, N = 10$): seven accelerators, six at $+2$, against three decelerators. Sustainment phase followed at 8.13 ($a = 9, N = 13$), with the same acceleration score as design, but N rose as affordability barriers, lagged readiness, and lagged systemic connectivity activated. Origin scored 6.53 ($a = 5, N = 9$), with fewer themes. The phase-standardized acceleration of active implementation dropped to 3.92 ($a = 5, N = 15$), the lowest across the lifecycle. Its raw acceleration matched origin, but N nearly doubled.

Across the policy cycle, four decelerators recurred in three or more phases: policy complexity, financial resources, lagged readiness, and lagged systemic connectivity. The remaining four appeared in a single phase only: lacking observability, lagged acceptance, and uncontrollable events in active implementation, and adopter affordability in sustainment. Most accelerators recurred persistently across all phases.

The cumulative trajectory of major policy actions

We traced the cumulative trajectory of major DTx policy actions from January 2022 to October 2025 and compared it against the canonical S-shaped adoption curve predicted by Diffusion of Innovations theory (Fig. 3).

The canonical S-curve predicts a slow start, accelerating uptake, and a gradual plateau. The observed DTx policy-focused trajectory was front-loaded, showing immediate acceleration in the early phases, followed by a sequence of gradually consolidating actions in 2023–2025, and a steeper acceleration in the later early-sustainment phase.

Discussion

Principal findings

The Hainan DTx policy package advanced through four lifecycle phases, expanding from two active policy measure categories at origin to six during active implementation, then consolidating to four in early sustainment (Fig. 1). The lifecycle analysis captures not only changes in policy content, but also shifts in policy venues, lead agencies, and stakeholder participation (Table 1). Across the four phases, Hainan's DTx policy package expanded from a health commission-led agenda-setting effort into a cross-sectoral policy system, and then narrowed toward regulatory pathway, evidence generation, and globalization during early sustainment. 76% of measures translated into concrete follow-up action on time, 14% showed moderate timeliness, and 10% were weak. Timeliness varied by domain: administrative and regulatory measures advanced rapidly, and financing and data-governance measures advanced more slowly. Accelerating determinants were structural and persistent across the lifecycle. Decelerating determinants were mixed: four persisted across most of the lifecycle (complexity, financial resources, lagged readiness, and lagged systemic connectivity), while the rest were transient and phase-specific. The net score of determinant influences was highest in the design phase and lowest in active implementation, where the number of active themes roughly doubled and most of the new themes were decelerators.

Timeliness as a service outcome

Implementation science has established a taxonomy of implementation and service outcomes (20, 36–38), yet the temporal dimension of implementation has rarely been measured directly. The Institute of Medicine identified timeliness as a core dimension of health service quality in 2001 (39), and the Framework to Assess Speed of Translation provided a structure for studying implementation speed (26). This study contributes an empirical operationalization of timeliness as a measurable service outcome at the policy level.

The deadline-anchored rubric defines timeliness through two observable criteria: whether a subsequent operational action occurred before the predefined deadline, and whether that action was concrete and DTx-specific. Timeliness functions as a service outcome: it becomes observable early, before later outcomes can be assessed, and the distribution of strong, moderate, and weak translation shows where a complex intervention is moving into routine governance and where it has stalled.

Strong timeliness fits administrative and regulatory measures, while the three moderate measures had DTx objectives incorporated into broader emerging-technology policies, a path that suits measures depending on multi-stakeholder negotiation or clinical workflow re-design. The two weak measures, Internet-hospital integration and equity financing, mark domains where institutional and fiscal groundwork or private players may come first; here a deliberate speed reflects the cross-sectoral negotiation and institutional safeguards that protect accountability. Across the three levels, this distribution works as a diagnostic signal that locates where structural alignment already enables fast action, where institutional and social readiness builds more slowly, and where a policy domain is ready for evaluation.

Speed as a multidimensional process

Diffusion of Innovations theory holds that cumulative adoption traces a smooth S-shaped curve, beginning slowly, accelerating through a take-off period, and leveling off at saturation (9). Prior work has widely applied this theory to health policy and system research (12, 40), as well as assessing determinants and stakeholder experiences of digital health implementation (41–43). The Hainan case extends this theory in digital health policy implementation research in three directions.

First, speed differed across measure domains within a single policy package. Administrative and regulatory measures, including clinical trial centers, medical device classification guidance, and dissemination platforms had timelier implementation. Financial and data-governance measures, including payment-reform integration, equity financing, and real-world data use, implemented slowly or inadequately. Prior implementation-speed research has largely treated speed as a single variable (17, 44), and this case shows that the domains of one policy move at different speeds.

Second, the cumulative trajectory of major policy actions formed a different shape from the canonical S-curve (Fig. 3) (9). The trajectory rose steeply at the start, as the origin, design, and active-implementation phases followed one another across 2022. It flattened through 2023 and 2024, then rose steeply again in early sustainment. This shape is steep at both ends and flat in the middle, the inverse of the canonical S-curve, which rises slowly, steepens in the middle, and levels off at the end. The phase-standardized acceleration (a_s) traces this same shape from the determinant side, aligning with the steep ends and flat middle of the trajectory. The phase-standardized acceleration thus mirrors the observed speed trajectory.

Third, the time dimension separated persistent from transient decelerators. Because persistent decelerators span the policy cycle, strategies set early can underestimate the barriers that surface at scale. Policy speed should respond dynamically to evolving evidence on effectiveness, demand, and risk (13). This pattern supports designing for dissemination from the outset (45), with early attention to payment integration, workforce readiness, and data governance for sustainability and equitable impacts (45, 46).

Methodological contributions

This study developed and illustrated three method advances for studying speed of implementation.

Timeliness rubric. First, the deadline-anchored rubric, combining a timeliness criterion and a specificity criterion, gives a reproducible way to measure a service system outcome that has been largely neglected and inconsistently measured (15, 17, 44, 47, 48). Applied to the 21 measures, the rubric produced a clear three-level split: strong, moderate, and weak. It is an initial template that needs a priori specification of predetermined deadlines or expectations for time to implementation, independent application, inter-rater reliability testing, and adaptation to settings where deadlines are implicit.

Documentary evidence as a data source for studying speed and timeliness. Second, this study used sources from official provincial policy documents from the Hainan government information disclosure system and agency websites, together with gray literature comprising provincial government WeChat communications, media press releases, and digital-health industrial reports (the full corpus is listed in Supplementary File 1, phase narratives in Supplementary File 2, and determinant ratings with supporting quotes in Supplementary File 4). This approach captures the institutional timeline, requires no participant recruitment burden, and draws on publicly available, non-human-subjects data. The lifecycle trajectory (Fig. 3) shows a visualization format that policy agencies could adapt for real-time monitoring. Thus, this study advances the range of low-burden and publicly available data sources for studying speed.

Analytic template for technology-policy speed research. Third, the study sets out a reusable approach for examining the speed of technology-innovation policy: mapping each lifecycle phase by its active policy measure categories and scope, as well as actor, setting, and timing (Fig. 1; Table 1); mapping policy measure and domain, and assessing policy measure timeliness against predefined milestones (Table 2); characterizing accelerating and decelerating determinants with a structured rating scheme (Fig. 2); and tracing the cumulative implementation trajectory against a reference DOI S-curve (Fig. 3).

Limitations

This is an observational embedded single-case study of one jurisdiction, which limits generalization: Hainan's free-trade-port status grants regulatory autonomy and expedited pathways that many other settings lack, so the speed patterns observed here may not transfer directly. The case is informative for theory-building, and multi-site comparison is needed to test how far these patterns extend. The documentary corpus captures the formal institutional record, so informal coordination and preparatory work may be undercounted (49). The determinant ratings are ordinal and interpreted qualitatively. The timeliness rubric is newly proposed and needs independent validation, including inter-rater reliability testing across coder teams and adaptation to settings with implicit deadlines. Reliance on publicly disclosed documents introduces potential disclosure bias, which the gray-literature corpus reduces but does not remove.

Future directions

A rate-limiting determinant hypothesis (i.e., that an implementation rate ceiling exists, set by determinants that resist acceleration even under favorable implementation conditions) can be tested through comparative case studies across jurisdictions that implement similar digital-health policy packages, coding which determinants can be accelerated and which remain rate-limited in each setting. Cross-national comparison would show whether domain-differentiated speed holds beyond Hainan, and how digital-health policy timeliness differs between high-income and low- and middle-income settings. Future research can examine whether timeliness, as a service outcome, predicts later outcomes such as sustainment, population reach, and health equity. Because timeliness judged against a policy deadline is not necessarily timely from the standpoint of patients, providers, or other stakeholders, future work could select a benchmark that makes sense for provider and patient-level timeliness.

Conclusion

This study mapped the lifecycle phases of the Hainan digital therapeutics policy package, measured the timeliness of its policy implementation, and assessed the accelerators and decelerators in each phase. Of 21 measures, 76% reached dedicated follow-up action on time, while financing and data-governance measures were less timely. The cumulative trajectory of major policy actions formed the inverse of the canonical S-curve, and the phase-standardized acceleration mirrored this trajectory from the determinant side. Policy timeliness works as a diagnostic signal of where a policy should advance. The deadline-anchored rubric and lifecycle approach offer transferable tools for studying the speed of technology-innovation policy.

Declarations

Ethics, Consent to Participate, and Consent to Publish declarations: not applicable

Competing Interests

EP serves as a co-organizer of the Implementation Science Communications Collection "Advancing the Science and Metrics on the Pace of Implementation," to which this manuscript has been submitted. All other authors declare no competing interests.

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Author Contribution

ZW, EP, and JX conceptualized the study and developed the methodology. XX, YK, WL, and ZW collected the data. ZW, YK, WL, and XX conducted the data analysis. WL and ZW developed the visualizations. ZW, YK, WL, XX, and EP drafted the manuscript. ZW, EP, and JX revised the manuscript. JX acquired funding for the study. All authors reviewed and approved the final version of the manuscript, had full access to all study data, and accept responsibility for the decision to submit the manuscript for publication.

Data Availability

The datasets analyzed during the current study consist exclusively of publicly available government policy documents and gray literature. All documents are listed in Supplementary Table 1.

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Figures

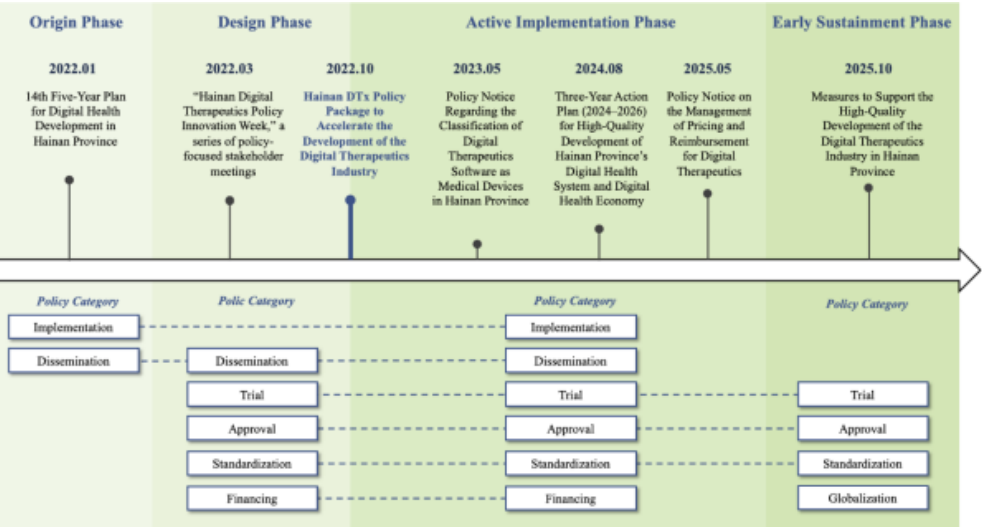


Figure 1



Figure 2

Accelerators and decelerators of the DTx policy implementation. Note. Green factors are the features of the innovation (i.e., the DTx policy); Purple factors are the adopter characteristics; Gray factors are the features of context; Upper ones with darker background are accelerators and lower ones are decelerators.

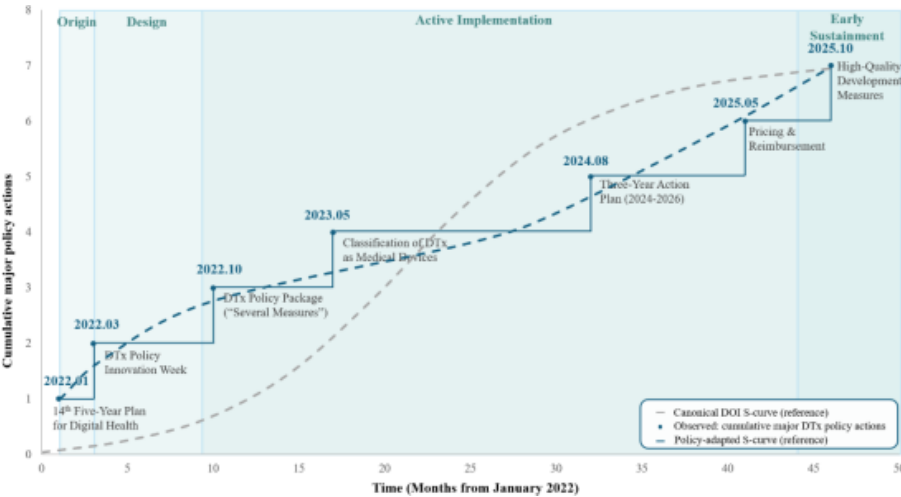


Figure 3

Cumulative trajectory of major DTx policy actions across the lifecycle, compared with reference DOI curves. Note. The step line shows the observed cumulative count of the seven principal DTx policy documents from January 2022 (month 0) to October 2025. The light dashed line is the canonical Diffusion of Innovations S-curve, and the bold dashed line is a policy-adapted S-curve, both shown for reference. The policy-adapted S-curve is steep at both ends and flat in the middle, the inverse of the canonical S-curve.

Supplementary Files

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