



BIM-Driven Software Productization in Architectural Practice: A Systematic Literature Review

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Keywords

Software Productization, Building Information Modeling, Digital Transformation, Interoperability, Technology Adoption, Architectural Practice, Cybersecurity.

Abstract

Software productization—the structured transformation of domain-specific internal tools into scalable, commercially viable solutions—has become a strategic imperative in architectural practice. Yet existing literature conflates productization with generic Building Information Modeling (BIM) adoption, leaving the product-development lifecycle, licensing architectures, and interoperability engineering underexplored. This systematic literature review synthesizes fifty-two peer-reviewed studies, industry surveys, and technical reports published between 2009 and 2025, retrieved from ScienceDirect, Web of Science, MDPI, and authoritative industry sources. The review applies the Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) frameworks to map the market adoption of BIM-based software across five domains: market foundation, technical implementation, user adoption, productivity results, and the barriers. Large architectural firms implement BIM technologies more successfully than SMEs owing to economies of scale, procurement mandate thresholds, greater IT infrastructure capacity, and the ability to absorb transitional productivity losses—factors that compound the capital and training differentials. Results measured quantitatively include such improvements as reduction in the number of coordination mistakes, faster project deliveries, and energy performance due to simulations provided by the application. Barriers include lack of semantic interoperability, security threats in the collaborative cloud-based systems, and organizational barrier. Furthermore, a structural gap has been identified in the existing literature regarding this issue. A comprehensive mapping of the complete productization lifecycle—from internal prototype through licensed commercial deployment—is absent from the synthesized literature on architectural practice. Policy and standardization implications are discussed, with recommendations for open-standard mandates and SME-targeted digitalization programs.

1. Introduction

The architecture, engineering, and construction (AEC) sector has undergone a sustained digital transition over the past two decades, driven largely by the maturation of Building Information Modeling platforms, cloud-collaborative design environments, and parametric design tools [1,2]. Within this transition, a distinct strategic phenomenon has emerged: software productization. Productization is formally defined here as the systematic process through which an organization transforms an internally developed, domain-specific tool into a scalable, commercially licensed product that addresses broader market requirements beyond the originating firm [3]. This process encompasses product-market fit analysis, API ecosystem design, versioning strategies, licensing models, customer onboarding frameworks, and long-term maintenance architectures—dimensions that distinguish productization from simple BIM adoption or digital workflow optimization.

Despite the conceptual clarity of productization as a business and engineering discipline, the existing AEC literature treats it primarily as a synonym for BIM implementation or digital transformation. It is important to acknowledge that architectural BIM cannot be entirely siloed from structural engineering workflows: architectural software productization must account for integration with structural engineering tools covering areas such as structural dynamics analysis, reinforced concrete detailing, and seismic evaluation. Modern tools, including generative AI-based text enhancement platforms and automated workflow generators, are also beginning to bridge the gap between internal prototypes and commercial SaaS solutions, further blurring the boundaries between disciplines. A structured gap therefore exists: no systematic review maps the complete productization lifecycle—from internal prototype through minimum viable product to commercially deployed, licensed SaaS solution—within an architectural practice context. This gap is consequential because the barriers to adopting an existing BIM platform differ substantially from the barriers to developing, commercializing, and sustaining one.

The global architecture software market was valued at approximately USD 6.85 billion in 2022, with compound annual growth rates projected to sustain expansion through 2030 [4]. This market size is indicative of industry-wide realization of the power of digital solutions, but significant differences exist in implementation levels across various types of organizations, geography, and specialization [4,5]. Organizations with substantial IT resources implement BIM more successfully than capital-constrained SMEs; this competitive gap requires targeted policy interventions [4].

The theoretical basis of this review includes two theoretical models: Rogers' Diffusion of Innovation theory [6] – explaining the rate of adoption and S-shaped growth in adoption of technologies by different categories of organizations, and Technology Acceptance Model (TAM) [7] –

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distinguishing between perceived usefulness and perceived ease of use as factors of adoption intentions. The theoretical models form the basis for analysis of adoption gaps and barriers within the literature.

The research questions of this literature review are: RQ1. What is the current status of the process of productization of BIM-based software within the architectural practice based on the literature? RQ2. What barriers exist in relation to the productization process? RQ3. Which policy, standardization and research interventions can be identified in the literature?

2. Methodology

This review follows a structured systematic literature review protocol adapted from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Database searches were conducted in ScienceDirect, Web of Science, MDPI Open Access, ACM Digital Library, and ASCE Library, supplemented by grey literature from McKinsey & Company, Autodesk industry reports, AEC Magazine, and CEMEX Ventures. Searches were conducted in April–May 2025.

Search strings combined Boolean operators across three concept clusters: ("BIM" OR "building information model") AND ("productization" OR "software product" OR "digital transformation" OR "technology adoption") AND ("architect" OR "AEC" OR "construction"). Synonyms and truncations were applied consistently across all databases.

Inclusion criteria required: (i) English-language publication; (ii) publication date 2009–2025; (iii) empirical data on BIM/architecture software adoption metrics, productivity outcomes, or barrier identification; and (iv) publication in a peer-reviewed journal, conference proceedings, or identifiable industry survey with stated methodology. Exclusion criteria eliminated purely conceptual opinion pieces without data, duplicate records, and sources inaccessible for full-text verification.

Initial database searches returned 312 records. After deduplication ($n = 47$ removed), title and abstract screening excluded 183 records. Full-text review of 82 remaining records excluded 30 further records for failing inclusion criteria, yielding a final synthesis set of 52 sources (20 primary peer-reviewed studies, 12 systematic or narrative reviews, 11 industry surveys or technical reports, and 9 book chapters or standards documents). Source classification is maintained throughout the review to distinguish evidence hierarchy: peer-reviewed empirical studies ($n=20$) are weighted most heavily, followed by systematic or narrative reviews ($n=12$), industry surveys or technical reports ($n=11$), and book chapters or standards documents ($n=9$). When synthesizing data from commercial sources such as Autodesk SmartMarket Reports or AEC Magazine, vendor-bias risk is mitigated by triangulating findings against independently published peer-reviewed studies and flagging commercially-sourced claims where independent corroboration is limited.

Table 1. PRISMA-adapted search and selection protocol

Stage	Records (n)	Action / Criterion
Database search	312	ScienceDirect, Web of Science, MDPI, ACM, ASCE, grey literature
Deduplication	-47	Exact and near-duplicate removal
Title/abstract screen	-183	Removed: off-topic, non-English, pre-2009
Full-text review	82	Assessed for inclusion/exclusion criteria
Excluded (full-text)	-30	No empirical data; duplicate; inaccessible
Included in synthesis	52	Final set: 20 empirical, 12 reviews, 11 surveys, 9 standards/books

3. Theoretical Framework

Two complementary frameworks underpin the analytical structure of this review. According to the DOI theory developed by Rogers [6], the technology adoption process is defined by the S-shaped curve through various adopter categories, such as innovators, early adopters, early majority, late majority, and laggards, and consists of five characteristics: relative advantage, compatibility, complexity, trialability, and observability. Within the framework of the AEC industry, BIM platforms reached the early majority adopter status for large organizations from 2013 to 2018; however, SMEs have reached this status as of 2025 in many markets.

Davis et al.'s Technology Acceptance Model [7] complements DOI by distinguishing two cognitive determinants of adoption intention: perceived usefulness (PU)—the degree to which a user believes the technology improves job performance—and perceived ease of use (PEOU)—the degree to which the technology is free of effort. In software productization, PU is shaped by workflow integration quality and quantified ROI evidence, while PEOU is shaped by user interface design, onboarding support, and training program quality. The persistent adoption barriers identified across the included literature map directly onto low PEOU perceptions (complex interfaces, training deficits) and contested PU perceptions (absence of standardized ROI benchmarks for SMEs).

Together, DOI and TAM inform the following research questions: RQ1 (Diffusion State) aligns with DOI's categorization of adopters, RQ2 (Barriers) aligns with TAM's PEOU and PU inhibitors, while RQ3 (Interventions) is targeted towards the policy and design levers to promote diffusion and acceptance. It is important to note that DOI and TAM are market adoption frameworks, not software development lifecycle models; they map how the market receives and integrates commercially deployed software, not how that software is engineered or productized internally. Development lifecycle considerations require separate frameworks such as Agile methodologies or Product-Service Systems theory.

4. Market Foundations and Growth Trajectories

In 2022, the global BIM market has grown to USD 6.85 billion, and forecasts by sector analysts predict further compound annual growth [1]. Ribeiro et al. note that the construction industry remains one of the least digitized sectors [2], highlighting substantial potential for productization growth. The estimation by McKinsey of the value that can be created through industry digital transformation is 1.6 trillion USD per year [2].

Adoption patterns, however, are highly heterogeneous. The Autodesk SmartMarket Report [3] documents that BIM implementation rates correlate strongly with firm size: large firms (>250 employees) in North America and Western Europe report BIM deployment on more than 70% of eligible projects, while firms with fewer than 50 employees report rates below 30%. This firm-size divergence is consistent across geographic markets surveyed by Brozovsky et al. [4], who reviewed 87 research papers related to the adoption of digital technology in the AEC sector and

discovered that organizational size is the main predictor of successful adoption, while project complexity and procurement demands follow next.

From a productization perspective, this adoption asymmetry creates a structurally segmented market: enterprise-tier products (e.g., Autodesk Revit, Bentley Open Buildings) dominate the large-firm segment through subscription licensing and API-rich ecosystems, while the SME segment remains underserved by affordable, interoperable, lower-complexity alternatives. This gap represents both a commercial opportunity and a policy challenge.

Table 2. IM adoption rates by firm size segment, based on synthesized survey evidence

Segment	BIM Adoption Rate (reported)	Primary Barrier	Source
Large firms (>250 staff)	>70% of eligible projects	Platform lock-in; upgrade cost	[3,4]
Mid-size firms (50–250 staff)	40–60% (variable by region)	Training capacity; integration complexity	[4,5]
SMEs (<50 staff)	<30% in most markets	Capital; IT support; ROI uncertainty	[3,4]
Emerging markets (non-OECD)	Data sparse; <20% estimated	Infrastructure; connectivity; standards	[5]

5. Technical Implementation

Technical maturity in AEC software productization is uneven across capability domains. Core 3D modeling and documentation have reached commodity status in medium-to-large practices, while advanced capabilities—parametric generative design, real-time structural analysis, 4D construction sequencing, and BIM-IoT integration—remain specialized deployments concentrated in large firms with dedicated technical staff [3,11].

Interoperability constitutes the most extensively documented technical barrier. Despite the existence of the Industry Foundation Classes (IFC) open standard, maintained by building SMART International, semantic fidelity losses during IFC roundtripping remain a persistent problem across software vendors. Brozovsky et al. [4] document that cross-platform data exchange introduces metadata truncation and geometric approximation errors that propagate into clash detection inaccuracies and quantity-takeoff discrepancies. BIM Collaboration Format (BCF) partially solves the issue tracking interoperability problem but fails to solve model federation integrity problems.

Cloud collaboration systems create latency issues for complex parametric models due to specific network architecture constraints: synchronous bidirectional data synchronization requirements, lack of edge computing integration, and the high polygon counts of Level of Detail 400+ models—such as highly detailed reinforced concrete wall nodes, complex structural connection assemblies, or seismic isolation components—can overwhelm standard cloud bandwidth allocations. Day [9] finds that infrastructure-level projects with model files exceeding several gigabytes lose acceptable performance in general-purpose cloud systems and require hybrid implementation strategies, increasing deployment costs. It is found by Mohammed et al. [12] that BIM-IoT integration systems for smart buildings greatly increase real-time processing needs and that mathematics modeling could help optimize the process.

Cybersecurity is a relatively unstudied aspect of the productization of architectural software. Cloud-based collaboration software exposes client project information to various security threats, including cyber-attacks, ransomware, and data sovereignty issues in international projects. Data sovereignty risks are particularly acute when proprietary structural calculations or sensitive building information are uploaded to cloud platforms hosted in foreign jurisdictions, where local data-access laws may conflict with client confidentiality obligations. Saeed et al. [13] identify access control, data ownership contractual provisions, and version control integrity as the three highest-priority cybersecurity concerns for AEC cloud platforms, yet most current architecture software licenses contain minimal security obligation language.

Table 3. Technical implementation maturity by capability domain with evidence classification

Domain	Maturity Level	Key Finding	Evidence Source	Study Type
Core BIM modeling	High	70%+ adoption in large firms; commodity capability	[3]	Industry survey (n=626 firms)
IFC interoperability	Moderate	Semantic loss in roundtripping; metadata truncation documented	[4]	Systematic review (87 studies)
Cloud collaboration	Moderate	Latency issues for >multi-GB models; hybrid deployment needed	[9]	Technical report
BIM-IoT integration	Low-Mod.	Optimization gains demonstrated; high compute demand	[12]	Empirical study
Cybersecurity frameworks	Low	Access control and data sovereignty gaps identified	[13]	Review (MDPI)
AR/VR workflow integration	Low-Mod.	Visualization gains confirmed; high training burden	[10,14]	Mixed empirical

6. User Adoption and Market Dynamics

Applying the TAM framework, adoption disparities across firm sizes reflect differential perceived ease of use rather than differences in perceived usefulness. According to Brozovsky et al. [4], all practitioners irrespective of their organization size perceive the worth of BIM workflow (PU is high); however, the perceived ease of use for BIM is low among small organizations (PEOU is low). This research was confirmed by findings in the American Institute of Architects Small Firm Exchange Annual Report [5], wherein an online survey of 423 small practice principals identified three main barriers to BIM adoption.

Professional resistance mechanisms identified in the literature correspond to specific TAM factors: cognitive load from interface complexity, and transition anxiety stemming from temporary productivity losses during platform migration. Arayici et al. [20] show that the implementation of BIM in the context of lean architecture necessitates organization change management and that firms have experienced 15–25% productivity decreases during the transition phase until they get to the steady state benefits.

Spatial heterogeneity in adoption patterns has been observed, but little research has been done on this issue. The selected literature comes mostly from North America, Western Europe, and Australia, limiting the applicability of these findings to regions in South Asia, Sub-Saharan Africa, and Southeast Asia where adoption may significantly differ due to technological infrastructure, connectivity, and regulatory issues.

Table 4. Technology Acceptance Model analysis of adoption determinants by firm size

TAM Dimension	Large Firms (>250)	SMEs (<50)	Evidence
Perceived Usefulness (PU)	High; ROI documented internally	High in principle; ROI unquantified for SME context	[4,5]
Perceived Ease of Use (PEOU)	Moderate; dedicated IT support available	Low; training burden and interface complexity dominant	[5,20]
Adoption intention	High; procurement mandates reinforce	Moderate-low; cost and PEOU barriers dominate	[3,4]
Transitional productivity loss	Managed; resource buffers exist	Significant (15–25%); existential risk for small firms	[20]

7. Productivity Outcomes and Benefits

The productivity evidence base for BIM implementation is substantial but heterogeneous in effect size and methodological rigor. The BIM Handbook [7]—the field's most frequently cited reference—synthesizes case evidence documenting coordination error reductions, construction change order frequency decreases, and shortened permit review cycles as consistent outcomes of mature BIM deployment. However, the Handbook appropriately notes that specific magnitudes vary considerably by project type, organizational maturity, and implementation scope.

The most methodologically rigorous quantitative evidence comes from controlled implementation studies. Azhar [18] conducted a cross-sectional analysis of 32 BIM implementation cases and reported mean cost savings of 7–10% of total project value attributable to clash detection and quantity-takeoff accuracy improvements, with ranges of 2–20% depending on project complexity. Zhang and Hu [19] demonstrated that 4D BIM-integrated construction sequencing reduced structural safety incidents by 34% relative to the pre-BIM baseline. Although their study context is a large-scale infrastructure project—which differs from typical architectural practice—the 4D sequencing methodology is directly applicable to complex architectural projects involving phased construction, deep basement excavation, or mixed-use high-rise developments where structural sequencing is critical. The finding is therefore included as indicative evidence of BIM-enabled safety performance, with the caveat that the magnitude may not be directly transferable to typical architectural-scale projects.

Energy performance benefits from integrated simulation tools are documented by Carrasco-Beltrán et al. [8], who report a 22% reduction in predicted energy consumption in a university campus renovation project deploying BIM-linked thermal simulation, compared to designs developed without integrated simulation. Mohammed et al. [12] show that BIM-IoT integration for post-occupancy building management can optimize HVAC energy consumption by 12–18% in monitored smart building installations.

Causal inference limitations must be acknowledged. All included productivity studies are observational or quasi-experimental; none employs randomized assignment. Firms that adopt BIM successfully may already possess superior management systems, experienced technical staff, and larger project portfolios—confounds that the available literature does not adequately control. Attribution of productivity gains solely to BIM software, absent controls for organizational quality, should be treated as an upper-bound estimate.

Table 5. Quantitative productivity outcomes from included empirical studies (effect sizes and contexts)

Outcome	Finding	Sample / Context	Study Type	Source
Cost savings (clash detection)	7–10% of project value (range 2–20%)	32 BIM implementation cases	Cross-sectional analysis	[18]
Safety incidents (tunnel project)	34% reduction vs. pre-BIM baseline	1 large infrastructure project	Quasi-experimental case	[19]
Energy performance	22% predicted reduction	University campus renovation	Implementation case study	[8]
HVAC optimization (BIM-IoT)	12–18% energy reduction	Smart building installations	Empirical monitoring study	[12]
Transitional productivity loss	15–25% decrease during deployment	Lean practice firms (qualitative)	Longitudinal observation	[20]

8. Barriers and Challenges

Barriers to architecture software productization operate across three interdependent domains: technical, organizational, and policy/market. This tripartite structure distinguishes this review's contribution from prior work that treats barriers primarily as technical or training-related phenomena.

Technical barriers center on interoperability and security. As documented in Section 5, IFC-based data exchange introduces semantic loss that current open-standard implementations have not fully resolved. Leite et al. [16] demonstrate that increasing Level of Detail (LOD) in BIM models—a productization requirement for high-fidelity downstream analysis—generates geometric complexity that degrades cross-platform translation accuracy, creating a tension between model richness and interoperability. Ding et al. [13 orig.] show that real-time IoT integration amplifies these challenges by requiring continuous bidirectional data synchronization across heterogeneous platform architectures.

Organizational barriers extend beyond training. Lu et al. [15] apply Activity Theory to BIM adoption in building operations contexts and find that technology implementation disrupts established social routines and role definitions within project teams—a finding that explains why training alone does not resolve resistance. For SMEs facing the documented 15–25% transitional productivity loss [20], mitigation strategies

include implementing structured educational modules delivered in phases aligned to project cycles, academic performance tracking tools that identify skill gaps before full deployment, and peer-network learning programs that leverage shared experience from firms that have successfully completed the transition. Wang et al. [14] document that AR/VR integration with BIM workflows requires not only technical skill acquisition but also fundamental workflow redesign, a change-management challenge that SMEs typically lack the organizational capacity to execute.

Policy and market barriers constitute this review's most novel contribution. The large-firm / SME adoption divide is not reducible to capital constraints alone. Procurement requirements in public-sector projects—which increasingly mandate BIM compliance in the UK (PAS 1192), Singapore (BIM Roadmap), and selected EU member states—effectively exclude SMEs that cannot achieve compliance without subsidized support. This creates a regulatory barrier that functions as a market concentration mechanism, reinforcing enterprise-tier vendor dominance. Addressing this divide requires policy instruments beyond market forces: training subsidies, open-standard mandates, SME digitalization grant programs, and procurement threshold adjustments calibrated to firm size.

Table 6. Tripartite barrier classification with evidence and sources

Barrier Domain	Specific Barrier	Evidence	Source
Technical	IFC semantic loss in roundtripping	Metadata truncation; clash detection degradation	[4,16]
	Cloud platform latency (large models)	Performance limits documented for >multi-GB projects	[9]
	Cybersecurity gaps in cloud collaboration	Access control and data sovereignty deficiencies	[13 Saeed]
Organizational	Transitional productivity loss	15–25% decrease during deployment (lean practices)	[20]
	Workflow and role disruption	Activity Theory analysis; SME change-management deficit	[15]
Policy/Market	Public-sector BIM mandates excluding SMEs	Procurement compliance requirements (UK, Singapore)	[5]
	Enterprise-tier vendor dominance	SME <30% adoption rate; licensing cost barriers	[3,4]

9. Identified Research Gap: The Productization Lifecycle

A structured review of the 52 included sources reveals that a comprehensive analytical mapping of the complete software productization lifecycle is absent from the synthesized literature. The existing literature covers discrete stages—technology adoption, barrier identification, productivity measurement—but does not synthesize how an internal architectural tool traverses the productization trajectory: problem-solution fit, minimum viable product development, licensing model selection (perpetual, subscription, SaaS), API ecosystem design, customer segmentation, onboarding architecture, versioning, support model, and long-term maintenance economics.

This gap is significant for three reasons. First, commercialization of internally developed tools is increasingly common among large architectural practices and specialist AEC technology firms, but proceeds without evidence-based frameworks. Second, the failure modes of AEC software productization—vendor lock-in, poor API design, inadequate security architecture, underestimated support costs—differ from adoption failure modes and require distinct analytical treatment. Third, policymakers designing SME digitalization programs need productization-aware frameworks to distinguish between supporting adoption (buying a commercial product) and supporting development (building one).

Future research should apply platform economics and product-service systems theory to the AEC software domain, map real-world AEC productization trajectories through longitudinal case studies, and develop evaluation instruments for productization readiness that practitioners and investors can operationalize.

10. Discussion

The synthesized evidence supports three overarching findings. First, BIM-based software productization has achieved significant market maturity at the enterprise tier but remains structurally inaccessible to SMEs—a pattern that DOI theory predicts for technologies with high complexity and low trialability in resource-constrained adopter segments [6]. Closing this gap requires not only cost reduction in existing products but also design interventions that reduce PEOU barriers: simplified onboarding, modular capability deployment (pay for what you use), and community-supported training ecosystems.

Second, the technical interoperability challenge is partially institutional rather than purely engineering. IFC as an open standard is technically capable of representing most architectural model data; the persistent semantic loss documented in the literature reflects vendor implementation choices that prioritize proprietary extensions over open-standard fidelity—a pattern consistent with platform economics literature on ecosystem lock-in strategies. Regulatory intervention, such as EU procurement mandates requiring demonstrable IFC compliance, may be necessary to shift vendor incentives.

Third, the characterization of the large-firm/SME adoption divide as a policy problem is supported by the evidence reviewed, but the policy instruments must be specific. Generic digitalization subsidies without implementation support have shown limited effectiveness in analogous SME technology adoption contexts [2]. Effective interventions combine financial support with mandated training, peer-network mentoring, and procurement-side signals (e.g., requiring BIM compliance only above certain contract value thresholds, exempting micro-practices).

The geographic limitation of the evidence base is an important constraint on these conclusions. The majority of included empirical studies are drawn from North America, the UK, Australia, and Western Europe. Adoption dynamics in South Asia, Southeast Asia, and Sub-Saharan Africa—where infrastructure constraints, local regulatory environments, and market structures differ substantially—may invalidate these findings. Region-specific replication studies are a research priority.

11. Conclusion

This systematic review synthesized 52 sources to map the current state of BIM-driven software productization in architectural practice across five domains: market foundations, technical implementation, user adoption, productivity outcomes, and barriers. The review confirms that large architectural practices have achieved meaningful productivity gains from BIM software—including documented cost savings of 7–10%, construction safety improvements of up to 34%, and energy performance reductions of 12–22%—while SMEs remain structurally excluded from these benefits by capital, training, and policy barriers.

The most significant contribution of this review is the identification of a research gap that the field has not previously named: no existing study analyzes the complete software productization lifecycle—from internal prototype through licensed commercial deployment—within an architectural practice context. Filling this gap requires longitudinal case research applying platform economics and product-service systems frameworks to real-world AEC productization trajectories.

Policy recommendations supported by the evidence include: (i) open-standard mandates requiring demonstrable IFC compliance in publicly procured software; (ii) SME digitalization grant programs combining financial support with structured implementation assistance; (iii) procurement threshold adjustments exempting micro-practices from BIM compliance requirements below defined contract values; and (iv) investment in region-specific adoption research to generate evidence beyond OECD-dominated datasets.

Future research should prioritize: longitudinal productization lifecycle case studies; controlled or quasi-experimental productivity measurement designs that control for organizational quality confounds; and interoperability compliance audit frameworks applicable to procurement evaluation.

Author Contributions

H.P.: Conceptualization, Methodology, Data Curation, Writing – Original Draft, Writing – Review & Editing.

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