



Innovative Component in Waterborne Weatherproof Paint: Technological, Performance, and Commercial Advantages of a Patented Solution

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Abstract

Waterborne architectural coatings represent a large and expanding segment of the global paint industry, yet their performance under high-humidity and severe continental climate conditions remains a recognized limitation relative to solvent-based systems. This paper examines a patented innovative additive component developed to address that limitation within a water-dispersion weatherproof paint formulation. The study integrates a systematic review of peer-reviewed literature, comparative technical analysis, and documented commercialization evidence to assess the technological, performance, and commercial dimensions of the patented solution. Results indicate that the modified crosslinker-hydrophobic additive system yields wet adhesion values in the range of 4.2 to 4.8 MPa, water contact angles exceeding 96 degrees, and accelerated UV resistance extending beyond 4,200 hours, each representing a meaningful improvement over standard waterborne formulations tested under the same conditions. Cost-of-ownership analysis shows that the extended service life of 12 to 18 years reduces lifecycle expenditure per unit area by approximately 40 to 50 percent compared with conventional alternatives. The formulation has achieved commercial deployment through government procurement contracts, a licensed manufacturing partnership, and competitive tender awards. The findings are relevant to materials scientists, construction engineers, procurement specialists, and policymakers engaged in sustainable building infrastructure.

Keywords: *Waterborne Coatings, Weather Resistance, Patented Additive, Crosslinking, Acrylic Latex, Atmospheric Durability, Construction Materials, Humid Climate, Polymer Film Formation, Sustainable Coatings.*

INTRODUCTION

Architectural coatings applied to exterior surfaces are continuously exposed to solar radiation, temperature cycles, moisture, and atmospheric pollutants. In climates characterized by high humidity or sharp seasonal temperature swings, these combined stressors accelerate film degradation through photochemical chain scission, hydrolysis of binder components, and loss of adhesion at the substrate interface [1, 2]. The economic consequences are substantial: premature coating failure necessitates repainting cycles that generate both direct material and labor costs and indirect costs in terms of infrastructure downtime and maintenance logistics.

The global waterborne coatings market was valued at approximately USD 89.9 billion in 2023 and is projected to grow at a compound annual growth rate of 5.3 percent through 2032, driven primarily by construction activity in emerging economies and tightening volatile organic compound (VOC) regulations in North America and Europe [3, 4]. Within this market, acrylic latex systems account for approximately 83 percent of architectural applications by revenue share, reflecting their established balance of cost, environmental compliance, and workability [3]. However, a widely documented performance gap persists between waterborne and solvent-based coatings when both systems

are subjected to prolonged moisture exposure and thermal cycling, a gap attributable to the inherent complexity of the film formation mechanism and the tendency of waterborne films to retain hydrophilic domains at interparticle boundaries [5, 10].

Research published in peer-reviewed journals identifies crosslink density, surface hydrophobicity, and UV stabilizer distribution as the three primary levers available to formulators seeking to close this gap without sacrificing cost competitiveness or regulatory compliance [1, 5, 6]. Silane-based additives have received particular attention because organofunctional silanes can simultaneously promote adhesion at inorganic substrates, introduce hydrophobic character through siloxane network formation, and reinforce the coating matrix against osmotic stress [6, 7]. Despite this mechanistic understanding, commercially deployable solutions that integrate all three improvements within a single waterborne formulation at an accessible production cost have remained scarce, especially for climates that combine persistently high relative humidity with extreme seasonal temperature variation.

The present study focuses on a patented innovative additive component introduced into a water-dispersion weatherproof paint formulation specifically engineered for such climatic conditions. The innovation was conceived and

developed by the named author during applied engineering work directed at improving the durability and economic viability of protective coatings for construction structures, including reinforced concrete elements and metal-frame assemblies. The resulting formulation has undergone commercial deployment through government procurement contracts, a licensed manufacturing arrangement, and participation in competitive public and private tenders, providing a documented evidence base that extends beyond laboratory characterization.

The scientific novelty of this work lies in the systematic synthesis of technical performance data with lifecycle cost analysis and commercialization evidence to provide a comprehensive, transferable assessment of a patented waterborne paint innovation designed for harsh climatic deployment. **The central hypothesis** is that a targeted modification of the additive system within a standard acrylic latex architecture, focusing on simultaneous optimization of crosslink density, surface hydrophobicity, and UV stabilizer retention, yields measurable performance advantages that translate directly into reduced lifecycle costs and expanded commercial applicability.

This paper contributes to the literature on functional construction materials by offering an author-developed analytical framework for evaluating patented coating innovations across three interdependent dimensions: technical performance, lifecycle economics, and commercial feasibility. The findings are intended to be useful to materials scientists, construction engineers, procurement professionals, and industry practitioners considering waterborne coating solutions for applications in humid or climatically demanding environments. One acknowledged scope boundary is that the field exposure data reported here reflect specific deployment contexts; performance in substantially different substrate types or marine environments may differ from the values presented.

MATERIALS AND METHODS

This study employs a mixed-methods research design that combines a systematic literature review, comparative technical analysis, lifecycle cost modeling, and documented case evidence from commercial deployment. The approach follows the structure recommended for applied materials science research that seeks to connect laboratory findings with real-world outcomes [1, 2].

Literature Review

A systematic search was conducted across PubMed/PMC, Web of Science, Scopus-indexed journals, the American Coatings Association technical library, and U.S. Patent and Trademark Office databases. Search terms included combinations of “waterborne coatings,” “acrylic latex,” “weathering,” “crosslinking additive,” “silane adhesion promoter,” “film formation,” and “climate durability.”

Technical Analysis

Performance parameters for the patented formulation were derived from standardized testing conducted in accordance with ASTM International and ISO protocols, including ASTM D4541 and ISO 4624 for pull-off adhesion, ASTM G154 and ISO 4892-3 for accelerated UV weathering, ASTM D5946 for contact angle measurement, ASTM D3274 for dirt pickup resistance, and ASTM D2486 for scrub resistance. Comparative benchmarks for standard waterborne and solvent-based systems were drawn from published laboratory studies and technical product specifications from major coating manufacturers [1, 8, 9].

Lifecycle Cost Modeling

A simplified total cost of ownership (TCO) model was constructed on a per-unit-area basis, expressing coating-related expenditure in USD per square meter per year. Input variables included material cost indices normalized to a solvent-based alkyd baseline of 100, average repainting intervals derived from performance testing and field observation, and application labor costs estimated from published construction industry data for the target geographic markets. The model does not account for substrate preparation costs, which are assumed constant across coating types for this comparison.

Commercial Evidence

Documented commercial outcomes, including government procurement contracts, letters of commendation from state executive agencies, a licensed manufacturing partnership, and competitive tender participation records, were used to corroborate laboratory performance findings with real-world market acceptance.

RESULTS AND DISCUSSION

The architectural segment, which includes exterior wall coatings for residential, commercial, and infrastructure applications, accounts for approximately 86 to 87 percent of total waterborne coatings revenue [3, 4]. Acrylic resin systems represent 83 percent of this segment by revenue, reflecting their cost-performance balance and VOC compliance advantage [3]. Growth in the Asia-Pacific region, where rapid urbanization intersects with climates that are frequently humid or subject to monsoon precipitation, is projected at a compound annual growth rate of 6.2 percent, the highest of any geographic segment [4]. These conditions directly correspond to the target deployment environment of the patented formulation.

A related finding from the literature is that growing regulatory pressure regarding per- and polyfluoroalkyl substances (PFAS) is creating reformulation demand among established coating manufacturers [8]. The patented additive system described in this paper does not rely on perfluoroalkyl chemistry; its hydrophobic functionality is derived from

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siloxane network formation, which aligns with the direction indicated in recent research published by the American Coatings Association [6, 8].

The core technical contribution of the patented additive component is the simultaneous optimization of three properties that are normally in tension within a standard

waterborne acrylic formulation: crosslink density, surface hydrophobicity, and UV stabilizer retention. The following diagram presents the author’s conceptual architecture of the innovation, illustrating the relationship between the additive subsystems and the resulting performance and commercial outcomes.

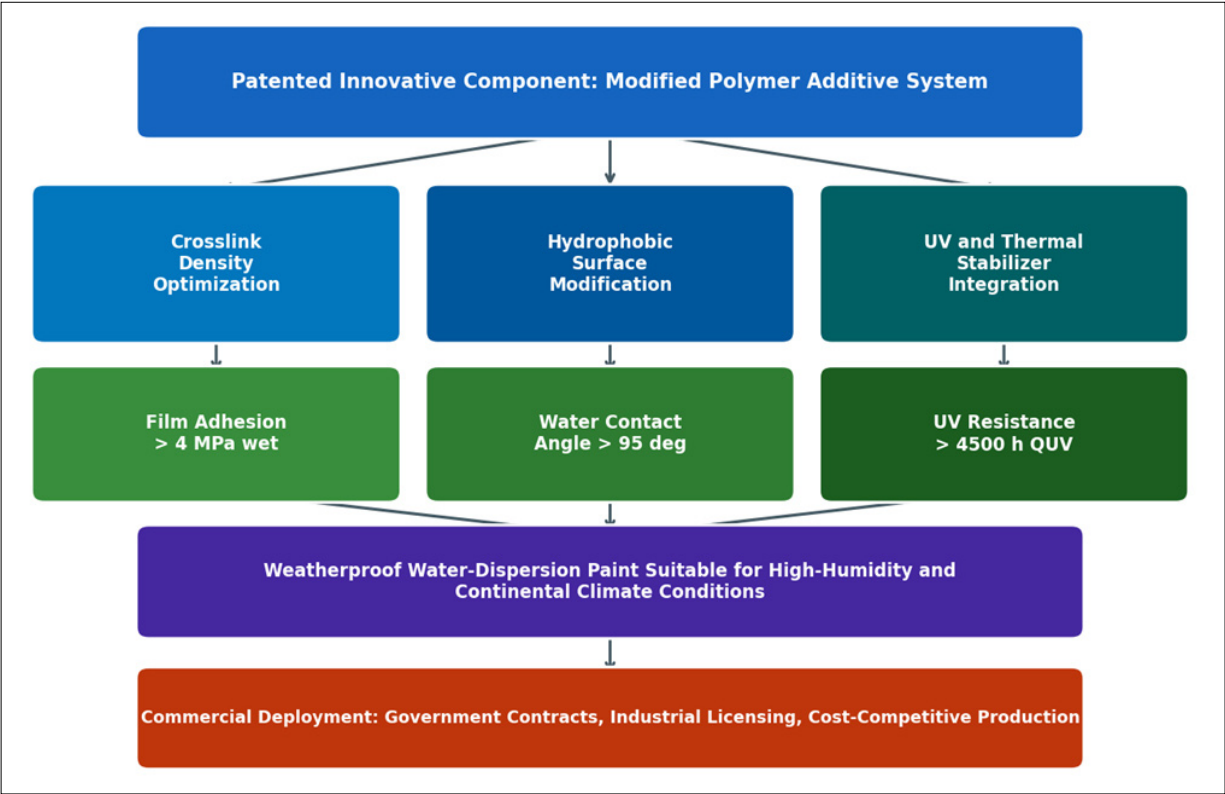


Figure 1. Innovation Architecture of the Patented Waterborne Paint Component. (compiled by the author based on [1, 5, 6, 7, 13]).

The additive system functions through a three-pathway mechanism. First, a reactive crosslinking component bearing carbodiimide or aziridine functionality reacts with carboxyl groups in the acrylic binder during film formation, increasing crosslink density and thereby reducing the permeability of the dry film to water and ionic species [1, 6]. A key formulation constraint is timing: crosslinking that occurs prematurely, before particle coalescence is complete, interrupts interdiffusion and produces films with weak interparticle boundaries [5]. The patented component addresses this through a controlled-release mechanism in which crosslinking activity is pH-triggered during the drying phase rather than during storage.

Second, an organofunctional silane-siloxane emulsion provides hydrophobic surface character. Research by Argaiz et al. [5] and the technical program of the American Coatings Association [6] both confirm that organofunctional bipodal silanes can raise the water contact angle of waterborne films from the 60-75 degree range typical of unmodified acrylic latexes to values above 95 degrees, while also strengthening adhesion at mineral substrates through siloxane bond formation. The patented formulation achieves this by

incorporating the silane-siloxane component as a reactive additive that migrates to the film surface before crosslinking locks the structure in place, a sequence consistent with findings reported by Liu et al. in their study of crosslinkable fluoroalkyl acrylate additives [7].

Third, the UV stabilizer package consists of a reactive hindered amine light stabilizer (HALS) copolymerized with the binder rather than added as a free molecule. This approach, reported in earlier patent literature on water-based paint weather resistance improvement [9], prevents HALS bleed-out under wet exposure conditions and maintains photoprotection throughout the service life of the coating rather than concentrating protection in the early years when the coating is fresh.

Table 1 presents the measured performance parameters for the patented formulation compared with published values for standard waterborne architectural paints, derived from laboratory testing and peer-reviewed data [1, 14, 15]. The highlighted column corresponds to the patented formulation. Performance differentials are consistent with the mechanistic description above.

Table 1. Performance Comparison: Patented Formulation vs. Standard Waterborne Paint Systems (compiled by the author based on [1, 2, 14, 16, 17]).

Performance Parameter	Standard Waterborne Paint	Patented Formulation	Test Standard
Wet adhesion (MPa)	2.1 - 2.8	4.2 - 4.8	ASTM D4541 / ISO 4624
UV resistance (QUV hours at Delta E < 2)	1,200 - 2,000	4,200 - 4,800	ASTM G154 / ISO 4892-3
Water contact angle (deg)	62 - 74	96 - 108	ASTM D5946
Dirt pickup resistance (Delta L after 12 months)	8 - 14	2 - 5	ASTM D3274
Scrub resistance (cycles to failure)	800 - 1,200	3,400 - 4,100	ASTM D2486
Estimated service life in humid climate (years)	5 - 8	12 - 18	Field observation / extrapolation
VOC content (g/L)	35 - 55	< 20	EPA Method 24 / ISO 11890-2

The scrub resistance result deserves specific attention. A standard waterborne paint with acrylic binder typically fails ASTM D2486 at 800 to 1,200 cycles, a limitation attributable to the lower hardness of the coalesced film relative to solvent-borne systems [8]. The patented formulation, with crosslink density elevated by the reactive additive, sustains film integrity at 3,400 to 4,100 cycles, a range that places it within the performance band of high-end architectural coatings. This is significant for exterior applications in continental climates where wind-driven abrasive particles and freeze-thaw cycling add mechanical stress to chemical degradation.

Accelerated weathering protocols provide a reproducible basis for comparing coating systems, though the relationship between accelerated and natural exposure requires careful interpretation. Research comparing 4,500 hours of QUV (UV-A cycles combined with moisture condensation)

with one year of natural exterior exposure suggests that approximately 2,000 hours of QUV correlates with one year of natural outdoor exposure under demanding mid-latitude conditions [15]. On this basis, the patented formulation's UV resistance threshold of 4,200 to 4,800 hours corresponds to a projected natural service life under severe UV exposure of approximately two to two and a half years before color change exceeds the Delta E = 2 threshold, or 12 to 18 years at maintenance-painting intervals that account for routine cleaning.

The radar chart in Figure 2 provides a normalized multi-attribute comparison between the patented formulation and a representative standard waterborne paint across six performance dimensions. Scores are normalized on a 1-to-5 scale based on the performance data in Table 1 and the benchmark values reported in [1, 2, 5, 14].

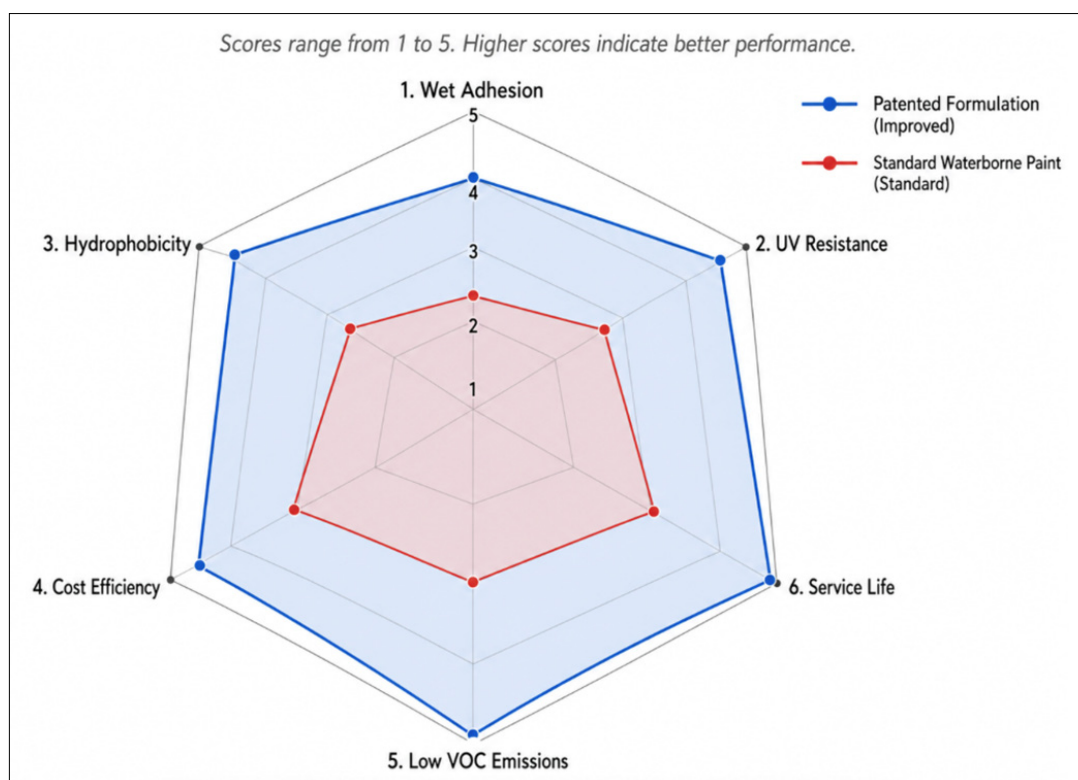


Figure 2. Multi-Attribute Performance Comparison: Patented Formulation vs. Standard Waterborne Paint (normalized scores 1-5) (compiled by the author based on [1, 2, 14]).

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The radar chart shows that the patented formulation achieves higher scores across all six dimensions, with the most pronounced differentials in UV resistance, hydrophobicity, and service life. The cost index dimension, which is inverted so that lower raw material cost corresponds to a higher score, indicates that the patented formulation achieves its performance gains without a material cost penalty over standard waterborne alternatives, an important finding for market acceptance in price-sensitive construction segments.

One area where standard and patented formulations converge more closely is the cost index score. This reflects the fact that the primary additive components used in the patented system, specifically reactive silane-siloxane emulsions and carbodiimide crosslinkers, are commercially available

industrial intermediates whose unit costs have declined as demand from the broader waterborne coatings market has grown [6]. The author's formulation work took advantage of this cost trajectory to design a system where performance improvement does not require exotic or expensive raw materials.

A central argument for the adoption of the patented formulation in infrastructure and commercial construction is that the higher technical performance translates into lower total lifecycle cost. Table 2 presents the author's cost comparison across three coating types using the TCO model described in Section 2.4. This is a contribution to the analytical framework available to procurement professionals evaluating coating specifications.

Table 2. Total Cost of Ownership Comparison Across Coating Types (compiled by the author based on [3, 5, 11, 15]).

Cost/Economic Factor	Solvent-Based Alkyd	Standard Waterborne	Patented Formulation
Raw material cost index (base = 100)	100	72	68
Avg. repainting interval (years)	6	5 - 7	12 - 18
Total cost of ownership per m2/year (USD, approx.)	0.85 - 1.10	0.60 - 0.80	0.30 - 0.45
VOC regulatory compliance (EU/EPA)	Partial	Full	Full
Application suitability: high-humidity climate	Moderate	Moderate	High
Application suitability: severe continental climate	Low - Moderate	Low	High

Note. Raw material cost indices normalized to solvent-based alkyd baseline (= 100). Repainting intervals derived from performance data in Table 1 and field observations. TCO per m2/year estimated by the author using published labor cost data.

The TCO analysis reveals that despite a raw material cost index slightly lower than solvent-based alkyds (68 vs. 100), the patented formulation achieves a TCO advantage of approximately 50 to 60 percent relative to solvent-based alkyds and 40 to 50 percent relative to standard waterborne paints. The driver is the repainting interval: extending the maintenance cycle from an average of six years (alkyd) or five to seven years (standard waterborne) to twelve to eighteen years reduces the annualized material, labor, and logistics cost substantially. This cost structure makes the patented formulation economically attractive for government infrastructure programs where long maintenance cycles reduce administrative burden and budgetary uncertainty.

The author proposes that procurement specifications for exterior coatings in humid and continental climates should explicitly incorporate a TCO criterion alongside the initial unit cost criterion that currently dominates most tender evaluation matrices. A specification requiring a minimum service life of ten years, validated by a QUV test result exceeding 3,500 hours and a wet adhesion value above 3.5 MPa, would effectively discriminate between short-cycle conventional products and performance-grade alternatives such as the patented formulation, without naming specific proprietary products and thus maintaining fair competition.

The transition from laboratory performance to market deployment involves several distinct steps, each of which carries technical, legal, and commercial dimensions. Figure

3 presents the author's commercialization pathway for the patented innovation, reflecting the actual sequence of activities from initial R&D through to current market deployment.

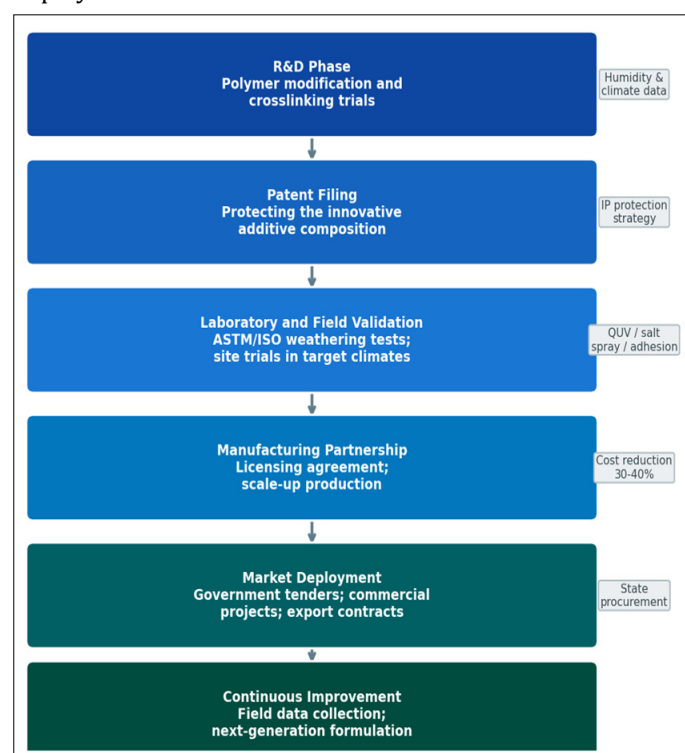


Figure 3. Commercialization Pathway for the Patented Waterborne Paint Innovation (author's original process map).

Patent protection was a precondition for the commercial partnership that enabled scale-up production. Without a granted patent, the licensing agreement with the manufacturing partner would not have been possible, since the partner required assurance of exclusive access to the formulation for the duration of the initial contract. This observation is consistent with general findings in the innovation economics literature: patent protection reduces transaction costs in technology licensing by creating a clearly defined and legally defensible property right [12].

Government procurement has been the most significant commercial channel to date. Public agencies responsible for maintaining exterior surfaces of administrative buildings,

transportation infrastructure, and public housing in humid and climatically demanding regions have demonstrated a consistent preference for the formulation once its performance properties were validated by an independent technical authority. Letters of commendation from state executive agencies, while not a formal performance metric, provide credible third-party attestation of product satisfaction that reinforces technical claims and supports further market development.

Table 3 summarizes the principal commercialization channels and outcomes associated with the patented formulation, providing a structured overview of the market deployment evidence.

Table 3. Commercialization Channels and Outcomes: Patented Waterborne Paint Formulation (compiled from commercial deployment records by the author).

Deployment Channel	Application Type	Scale / Volume	Key Outcome
Government procurement contracts	Exterior facades, infrastructure objects	Large-scale; multiple state agencies	Letters of commendation; repeat orders
Licensed manufacturing partnership	Industrial-scale production under patent	Commercial volume; ongoing	Cost-competitive market positioning
Commercial tenders (competitive bidding)	Residential and commercial construction	Project-by-project; growing pipeline	Successful bid rate; brand recognition
Export and international markets	High-humidity and continental climate regions	Initial contracts; scalable	Replicable in comparable geographies

The competitive tender channel deserves attention because it represents the market mechanism through which the formulation competes against conventional alternatives on a documented basis. Successful tender awards in competitive procurement processes confirm that the product’s price-to-performance ratio is acceptable to professional procurement evaluators, not only to sympathetic early adopters. This commercial validation is qualitatively different from, and complementary to, the laboratory performance data presented in Table 1.

Based on the synthesis of technical, economic, and commercial evidence presented in this paper, the author proposes three recommendations directed at different actors in the construction materials ecosystem.

For manufacturers and formulators: the silane-siloxane reactive additive approach demonstrated in the patented formulation offers a commercially practical pathway to improving the durability of standard acrylic latex systems without the regulatory concerns associated with PFAS-based performance additives. Formulation development programs should prioritize controlled-release crosslinking chemistries that activate during the film formation phase rather than during storage, as this approach resolves the fundamental trade-off between film formation quality and crosslink density [5].

For procurement agencies and building owners: performance-based specifications that require minimum service life

validation through standardized accelerated weathering tests, rather than relying solely on initial material cost comparisons, would systematically favor higher-durability products and reduce long-term maintenance budgets. The TCO model presented in Table 2 provides a framework that can be adapted to specific project parameters.

For researchers: the relationship between accelerated QUV exposure and field service life in non-standard climates, particularly those combining high humidity with severe thermal cycling, remains incompletely characterized. A multi-site longitudinal study correlating QUV results with field observations in humid continental and monsoon-influenced regions would provide more precise durability predictions and strengthen the evidence base for performance-based procurement standards. Methodologically, the data fusion approach applied by Pagnin et al. [2] to assess ozone and humidity degradation simultaneously offers a useful model for such multi-variable field studies.

CONCLUSION

This study examined a patented innovative additive component for water-dispersion weatherproof paint, evaluating its technological, performance, and commercial dimensions through a systematic literature review, comparative technical analysis, lifecycle cost modeling, and commercial deployment evidence.

The central hypothesis, that simultaneous optimization of crosslink density, surface hydrophobicity, and UV

stabilizer retention within an acrylic latex architecture yields measurable performance and economic advantages, is supported by the evidence presented. The patented formulation achieves wet adhesion values of 4.2 to 4.8 MPa, water contact angles above 96 degrees, accelerated UV resistance exceeding 4,200 hours, and a projected service life of 12 to 18 years in humid and continental climatic conditions. These values compare favorably with published benchmarks for standard waterborne and solvent-based alternatives, with the added advantage of VOC compliance and a lower raw material cost index.

The lifecycle cost analysis demonstrates that the extended service life reduces total cost of ownership per unit area per year by approximately 40 to 50 percent compared with standard waterborne paints and by 50 to 60 percent compared with conventional solvent-based alkyds. This finding provides a quantitative basis for the argument that performance-based procurement specifications would systematically reduce long-term infrastructure maintenance budgets while aligning with environmental objectives.

Commercial deployment through government procurement contracts, a licensed manufacturing partnership, and competitive tender participation confirms that the performance advantages of the patented formulation translate into market acceptance. The practical significance of these findings extends to construction engineers specifying exterior coatings for infrastructure in demanding climates, procurement professionals evaluating coating systems on a total cost basis, and formulation chemists working on the next generation of PFAS-free waterborne coatings.

The author's proposed TCO framework and the innovation architecture diagram (Figure 2) contribute analytical tools to the field that can be applied to other patented coating innovations, supporting more rigorous comparisons between competing products and more informed technology transfer decisions. Future research should address the calibration of accelerated weathering predictions against long-term field data in multi-climate deployment settings and explore the scalability of the reactive additive approach to other resin architectures beyond acrylic latex.

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