[DA-027] GIS&T in Insurance

Abstract

This article explores the historical and modern intersections of GIS&T and insurance, emphasizing how location intelligence has always been central to risk evaluation. It examines the current applications of GIS&T in insurance, including improved data collection, visualization, real-time risk monitoring, and dynamic pricing models like parametric insurance. Furthermore, it investigates how GIS&T is transforming insurance portfolio management through geographic concentration analysis, market penetration strategies, and network optimization. Looking ahead, the paper discusses the integration of GIS&T with emerging technologies such as artificial intelligence and digital twins to enhance predictive modeling and climate resilience. As the frequency and severity of natural disasters rise, insurers are leveraging GIS&T not only to assess risk but also to proactively mitigate losses and bolster community resilience.

Keywords: business, climate change, digital twins, economic aspects, risk

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Explanation

1. Insurance Has Always Been a Story of Location
2. Insurance Now
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4. GIS&T in Insurance Going Forward

1. Insurance Has Always Been a Story of Location

Imagine you're a merchant in Boston in August 1800, standing in a newly established insurance office, carefully plotting the course of your schooner Eagle to the Caribbean. The journey's risk assessment wasn't based on sophisticated satellite data or computer models, but rather on the collective wisdom of the company's directors who understood the geographical perils intimately - from the privateers lurking near Guadeloupe to the seasonal hurricane patterns that could spell disaster for a sugar-laden vessel.

This geographical understanding of risk wasn't new even then. In the 1750s, Philadelphia merchants had developed intricate networks of correspondents who would send detailed reports about conditions in various ports, the safety of different routes, and the political situations that could affect marine commerce. These early insurers knew that a voyage from Philadelphia to Barbados carried different risks than one to Jamaica, and they priced their policies accordingly. They understood that a ship taking the windward passage through the Caribbean faced different hazards than one on the leeward route.

The marine insurance business was fundamentally about understanding geography - where ships were coming from, where they were going, and what lay between. Insurers would pore over letters from ship captains describing treacherous shoals, study reports of privateering activity along certain routes, and track seasonal weather patterns that could imperil their investments. A policy for a winter Atlantic crossing would cost more than a summer voyage, reflecting the heightened risk of storms. Routes that skirted hostile territories commanded higher premiums than those through friendlier waters (Farber, 2021).

This geographical understanding of risk laid the foundation for modern insurance practices. While today's insurers use sophisticated GIS tools to analyze risk patterns, the fundamental principle remains unchanged: location matters. The 18th-century merchant examining hand-drawn charts and the modern analyst studying satellite data are engaged in the same essential task - understanding how geography shapes risk.

2. Insurance Now

Insurance has come a long way since those early days. If the global insurance industry were a country, it would be the world's third-largest economy at $7 trillion (Staib and Puttaiah, 2019), larger than Japan and Germany combined, trailing only the United States and China. This massive number, however, merely hints at insurance's true impact, which extends far beyond premium collection to enabling economic activity at every scale—from your local coffee shop to SpaceX rockets, from home renovations to Apple's global supply chain.

Think about what you did today. Drove a car? Worked in an office building? Ordered something online? Used electricity? Insurance made all of that possible. Without it, banks wouldn't lend money for construction, ships would stay in port, entrepreneurs would shy away from risk, and the sharing economy would remain just an idea. The industry doesn't just protect against risk, it transforms uncertainty into manageable costs that fuel innovation and commerce.

Consider these numbers:

- The industry's $35 trillion investment portfolio exceeds the combined GDP of the US and Germany
- Marine insurance facilitates $15 trillion in global trade annually, equivalent to China's entire economy
- Construction insurance underwrites $10 trillion in global building projects
- Insurance innovation creates entirely new industries, from ride-sharing to commercial space flight

Insurance functions as the operating system of the modern economy—running quietly in the background while powering everything we do. While many view insurance as a contingency plan, its true value lies in converting seemingly impossible risks into calculated business opportunities. From enabling the Industrial Revolution through boiler insurance to protecting tomorrow's autonomous vehicles and space exploration, insurance transforms the unthinkable into the achievable. It's a remarkable evolution for an industry that began with merchants sharing shipping risks centuries ago.

3. GIS&T in Insurance Today

Think of how those early insurance companies used maps and letters from ship captains to figure out if a voyage was too risky. Today's insurers are doing the same thing but with (much) more modern tools. While it’s practically impossible to quantify the use of GIS technology in the insurance industry, Esri, a leading provider of GIS software, reports that many of the world's largest insurance companies have been leveraging their analytical tools for over 30 years. These tools assist insurers in guiding more sustainable strategies, including scalable portfolio management, real-time threat monitoring, and enhanced workflows (Esri, n.d.).

Instead of relying on hand-drawn maps and word-of-mouth reporting, insurance companies now use GIS&T to parse and understand risk at hyper-detailed levels.
This section looks at three main ways insurance companies are using GIS&T today. First, we'll explore Risk Assessment and Pricing - essentially, how companies figure out what to charge for coverage based on location. Then we'll look at Risk Management, which is insurance jargon for handling claims (including disaster response). Finally, we'll dive into Insurance Portfolio Management, which helps companies make (smart) decisions about where they do business.

3.1 Risk Assessment and Pricing

The core of insurance has always been about understanding and pricing risk based on location. But while those Boston merchants in 1800 relied on letters and personal networks to assess Caribbean trading routes, today's insurers use sophisticated geospatial tools to analyze and visualize risk in real time.

Underwriting
As an interesting historical note aside, the term "underwriting" has a great origin story that takes us back to Lloyd's Coffee House in 17th-century London. Ship owners would come in looking to protect their vessels and cargo during dangerous sea voyages. They'd describe their ship, the route, and the cargo. Those willing to take on the risk would (literally) write their names under the description and how much risk they were willing to accept. Once the voyage (risk) was covered, a line would be drawn below the names (and their corresponding contributions). Hence "underwriting." If anything happened to the ship, each "underwriter" would pay their share of the loss based on what they had committed to. Think of underwriting as insurance detective work, but today's detectives have tools that would seem like science fiction to their predecessors. GIS transforms underwriting in three key ways:

- **Enhanced Data Collection and Analysis**. Modern underwriting isn't just about knowing where something is - it's about understanding everything about that location. GIS lets insurers layer and analyze multiple data sources simultaneously, such as natural hazard exposure and vulnerability or infrastructure quality and emergency response capabilities. These layers come together through sophisticated algorithms and predictive models, helping underwriters spot patterns and relationships that would be impossible to see otherwise.
- **Visualization and Decision Support**. GIS turns complex data into clear visual stories. Underwriters can:

    - Map insured properties against risk zones, and
    - Create risk heat maps showing hazard concentrations.
- **Risk Analysis and Optimization**. The real power of GIS in underwriting comes from its ability to look both backward and forward:
    - Historical analysis: Understanding past patterns and claims experiences;
    - Future projection: Modeling climate change impacts and evolving risks.

This comprehensive view helps insurers design better products, set more accurate rates, and make smarter decisions about which risks to take on.

Pricing

Modern insurance pricing has evolved far beyond the simple rate tables of the past. Today, GIS enables two major innovations in pricing risk: dynamic pricing and parametric insurance.

- **Dynamic Pricing**. Progressive Insurance exemplifies how location-based data is revolutionizing traditional pricing models (Izaret and Schürmann, 2019). Using mobile telematics and real-time GIS data, insurers can now:
    - Adjust rates based on actual driving patterns and locations,
    - Factor in real-time conditions like weather and traffic, and
    - Offer personalized pricing that reflects true risk exposure.

While Progressive Snapshot doesn't directly use location data to price its discount, it does collect location data (which could be aggregated geographically and used for other purposes). Dynamic pricing, though, can cut both ways for insureds. For instance, a participant in the Snapshot program reported that throughout a 30-day trial period, they received periodic reports indicating their driving performance. The device would beep whenever they stopped abruptly, signaling a negative mark on their driving record. By the end of the trial, the driver achieved an A-grade and saved 20% on their car insurance premium (Smith, 2012). However, it's important to note that not all experiences with Snapshot are positive. Some users have reported rate increases due to driving behaviors deemed risky by the program. For example, one user experienced a rate increase of $244 after the device recorded frequent hard-braking incidents (Kase, 2024).

- **Parametric Insurance**. An equally revolutionary development is parametric insurance, which is a product that pays out automatically based on measurable events:
    - A farmer gets an automatic payment when rainfall drops below a certain level.
    - A coastal property owner gets paid when wind speeds exceed defined thresholds.

The keyword here is automatic, i.e., no lengthy claims process or claims adjusters. (Like with telematics, this type of insurance is not based on exact latitude and longitude coordinates, but on general geographical areas.) This approach particularly impacts microinsurance in developing markets, where traditional claims processes might be too costly or complex. Using simple, objective triggers, parametric insurance makes coverage more accessible and payouts more predictable. For example, BlueMarble works with Nespresso and coffee farmers across Indonesia, Kenya, Colombia, and Zimbabwe to offer affordable crop insurance that pays out without delay when bad weather impacts coffee production (Blue Marble Micro, n.d.).

Both approaches share a common thread - they use GIS to make insurance more precise and responsive than ever before. While understanding and pricing risk is fundamental to insurance, equally important is managing that risk once it's on the books. Just as GIS has transformed how insurers assess and price risk, it has changed how they handle everything from routine claims to major catastrophes.

Risk Management
What can happen at the tail-end of the insurance value chain, a risk coming to fruition, is as important to insurers as the analysis and pricing up front, and GIS&T plays into these as well.

Risk. GIS&T gives insurers a sharper view of their risk landscape, helping them manage exposure and stay aligned with their overall underwriting strategy. With spatial analysis, insurers can pinpoint where risks are piling up—whether it's high-value properties clustered in one area or multiple assets exposed to the same peril, like flood or wildfire. That kind of visibility helps avoid overconcentration. It also makes it easier to monitor risk appetite. Insurers can set clear limits on how much risk they're willing to take on in specific areas or for particular hazards. Real-time exposure tracking helps them stay within those limits—and within reinsurance agreements—by showing exactly where insured value is concentrated across geographies and product lines.

Take the AXA XL insurance company, for example. They use GIS tools to monitor exposure in California's wildfire-prone regions. That insight allows them to adjust their risk mix, allocate capital more efficiently, and lower potential losses during peak fire seasons (Ambourg, 2024). The bigger picture: by layering these tools together, GIS&T helps insurers stay disciplined, make smarter decisions, and strengthen profitability—all while managing risk with more confidence.

Claims Management. Remember how early insurers relied on sketched maps and written reports to assess damage? Today's claims handlers have a full digital command center at their fingertips. GIS transforms routine claims handling from a paper-pushing exercise into a streamlined, data-driven operation. Modern insurers use mobile technology to streamline the claims process:

- Adjusters use mobile apps to document damage, geotag photos, and estimate repairs on-site.
- GIS platforms help optimize adjuster territories and routes based on claim density.
- Digital mapping tools give adjusters instant access to property details and claim history.

GIS has also revolutionized fraud detection. Where investigators once relied on hunches and manual file reviews, they now have sophisticated spatial analytics at their disposal:

- Systems flag multiple claims filed for the same incident by analyzing location data.
- Spatial analysis helps identify networks of suspicious auto claims by mapping accident patterns.
- Geographic clustering algorithms detect potential fraud rings operating in specific areas.

Good thing, too, since the insurance claims services market was valued at $198.13 billion in 2024 and is projected to grow at a compound annual growth rate (CAGR) of 13.3% from

2025 to 2030 (Business Wire, 2024).

Disaster (Catastrophe) Management. Catastrophic losses have reached unprecedented levels in recent years, and the wildfires in California as of this writing are like an exclamation point. According to the Swiss Re Institute, natural catastrophes resulted in $100 billion in insured losses in 2023, the fourth consecutive year this number has grown, with total economic losses reaching $280 billion (and over 74,000 fatalities globally) (Banerjee et al., 2024).

Natural disasters mean intense activity for insurers. When major events strike, GIS has become critical for managing large-scale responses. Pre-event planning uses predictive modeling to prepare for disasters:

- Weather forecasting combined with property data helps position adjusters before storms.
- Catastrophe modeling uses GIS to project potential losses and adjust coverage strategies.
- Insurers map policyholder concentrations to understand exposure in disaster-prone areas.

Post-event response relies on GIS tools to coordinate complex responses:

- Drone and aerial imagery assess damages before physical inspections are possible.
- Real-time mapping tracks claim clusters to optimize resource deployment.
- Satellite imagery combined with property data helps fast-track obvious total losses

Insurance Portfolio Management

Just like a financial advisor helps balance your investment portfolio, insurers must balance their risk portfolio across different locations. GIS tools have transformed this from pushing pins into wall maps to sophisticated spatial analysis.

- **Geographic Concentration Management**. Modern insurers can't afford to have too much risk concentrated in one area. Think of it as not putting all your eggs in one geographic basket.
  - Digital mapping reveals where risks cluster - from flood zones to cyber threats.
  - Visualization tools spot areas where exposure might be too high.
  - GIS helps spread risk across different regions and perils.
  - Reinsurance decisions are optimized by understanding geographic exposure patterns.
- **Market Analysis & Penetration**. GIS turns market analysis from guesswork into science. Instead of relying on local agents' hunches about market opportunities:
  - Spatial analysis reveals market share patterns across territories.
  - Mapping tools highlight underserved areas ripe for expansion.
  - Geographic data provides insights into competitor presence and performance.
  - Growth opportunities emerge from analyzing demographic and economic patterns
- **Network Optimization**. Running an insurance business means managing complex networks of people and services. GIS helps optimize these networks:
  - Agent and broker territories are balanced for maximum efficiency.
  - Claims service providers are positioned where they're needed most.

- Vendor networks are mapped to ensure adequate coverage.
- Resources are allocated based on geographic demand patterns

These integrated view helps insurers make smarter strategic decisions about where and how to grow their business. As exciting and innovative GIS&T use has been in changing the way insurers operate, more exciting is what lies ahead. As technologies and capabilities evolve, the role of GIS in insurance will continue to grow.

4. GIS&T in Insurance Going Forward

Hockey legend Wayne Gretzky once famously said, "Skate to where the puck will be.” Given the ever-increasing costs of natural disasters, insurers need to skate toward claims mitigation (or prevention). There are (interconnected) actions that insurers can take, along with GIS&T, to do so. First, given that GIS data has improved dramatically, integrate more and better data sources to understand risk fully. This enhanced understanding enables real-time monitoring of risks as they evolve. These capabilities come together in building resilience, i.e., helping communities prepare for, withstand, and recover from disasters. Let's step through these in more detail.

4.1 Data Volume, Velocity, and Precision

GIS&T in insurance is entering a new phase. And it's not just because maps are getting better, but because the data fueling them is exponentially richer, faster, and more precise than ever before. This evolution enables faster, more accurate location analytics across the value chain. In claims, that means shorter cycle times. Adjusters equipped with geotagged imagery, drone footage, and high-resolution parcel data can now triage and assess damage remotely (sometimes within hours of an event), speeding up support for policyholders. After Hurricane Ian, for example, insurers used aerial imagery and location intelligence to rapidly identify total losses without waiting for physical inspections, cutting claims handling time by days (and improving customer satisfaction scores in the process) (Carvill, 2022).

In pricing, better data supports more dynamic models. Location-specific telematics, mobile sensors, and even embedded insurance products now allow risk to be priced based on hyperlocal exposure. Auto insurers using telematics, for instance, can combine driving behavior with road-type risk (urban grid vs rural highway) and even real-time weather data to adjust pricing and coverage on the fly. The bottom line: today’s GIS&T systems aren’t just better at visualizing risk, they’re built to respond to it, in real time, with the kind of precision that legacy systems simply weren’t designed to handle.

4.2 Integrations with Other Data & Technology

The future of GIS&T in insurance isn't just about better maps, it's about bringing together different types of data to paint a more nuanced picture of risk. Think of it as adding layers to a painting until you can see not just the immediate subject of the painting, but the history behind it.

Third-party Data Integrations. Third-party data integrations are already expanding what's possible. Beyond traditional sources like weather data and satellite imagery, insurers are starting to tap into:

- Indigenous knowledge about local environmental patterns,
- Human mobility data showing how people use spaces,
- Wearable health devices tracking real-time health indicators, and
- Cultural data that helps understand community behaviors and risks.

For example, GIS was combined with local knowledge for flood risk mapping in Vietnam's Thua Thien Hue province, demonstrating how this integration improved disaster management through community participation and better data collection. The project succeeded by fostering trust between communities and authorities while partnering with local universities to overcome technical challenges (Tran et al., 2009).

Smart Cities and Digital Twin Integrations. Smart Cities and Digital Twins add another dimension. Think of Singapore's "Virtual Singapore" project. It's like having a complete 3D digital copy of the city, showing everything from building heights to traffic patterns to drainage systems. Research indicates that over 500 cities are expected to implement digital twins by 2025, utilizing these virtual models to optimize infrastructure and sustainability efforts (ABI Research, 2021).

As cities deploy more sensors and IoT devices, these digital twins become living models that update in real-time. For insurers, this means:

- Understanding how flood waters might flow through city streets before it rains,
- Seeing how a new building might affect wind patterns and storm risks, or
- Testing how different emergency response routes perform during peak traffic.

This kind of dynamic modeling helps insurers move from reacting to risks to preventing them. When you can see how a city works - not just how it looks on a map - you can make smarter decisions about everything from pricing to disaster planning.

Artificial Intelligence (AI)/Machine Learning (ML) Integration. AI/ML Integration ties it all together. AI plays an important role in insurance product development, underwriting, claims processing, and customer service (Kabir, 2024). AI/Machine learning doesn't just help process all this data - it ties it all together and finds patterns humans might miss. This could revolutionize how insurers:

- Spot emerging risks before they become claims,
- Identify communities that might need extra support, and
- Predict where prevention efforts will have the biggest impact.

This integration of data and technology isn't just about better pricing or faster claims - it's the foundation for a more proactive approach to risk. When we understand risk better, we can do more to prevent losses rather than just pay for them.

Real-time Risk Monitoring
Insurance has traditionally worked by looking at historical data to predict future risks. But what if we could track risks as they develop? That's where real-time monitoring comes in.

Environmental Monitoring has become increasingly sophisticated. Modern GIS systems don't just map environmental hazards - they track them in real-time by integrating:

- Wireless sensor networks measure everything from water levels to soil conditions,

- Cloud computing platforms that process this data instantly, and
- Predictive models show how hazards might develop, which helps insurers understand not just where risks are, but how they're changing.

Disaster Risk Management has evolved from simple mapping to dynamic response systems. GIS now helps:

- Identify and classify disaster-prone areas,
- Monitor conditions that might trigger events, and
- Track how disasters unfold in real-time

But challenges remain - from data accuracy to system response times in crises.

Public Health Monitoring became especially relevant during COVID-19. GIS tools now enable:

- Real-time mapping of disease outbreaks,
- Prediction of spread patterns using travel data, and
- Identification of potential hotspots before they emerge

The University of Genova developed an integrated web-based GIS platform to manage and assess risk in complex port areas exposed to intense wind conditions. The system combines real-time monitoring through an extensive network of sensors, numerical simulations for wind forecasting, and statistical analysis to provide port operators with actionable safety and operational information. While initially focused on port management in Italy and France, the platform demonstrates how GIS technology can effectively integrate diverse data sources, real-time monitoring, and risk assessment tools into a unified system for managing complex infrastructure risks, offering potential applications for broader infrastructure and risk management scenarios (Repetto et al., 2018).

We've moved from looking at snapshots of risk to watching a live video feed. Better yet, we're not just watching - we can respond to what we see. This ability to spot and react to changing risks is exactly what we need for the next big challenges: risk engineering and climate resilience.

From Risk Transfer to Risk Engineering

Insurers have long been in the business of pricing uncertainty, essentially betting on the likelihood of bad things not happening. But with today's technology and data, there is a real opportunity to shift from gambling on risk to actively engineering against it. Instead of just transferring risk, insurers can help reduce it.

Leading commercial carriers like FM Global are already doing this. They send engineers to client sites, use GIS data to assess hazard exposures, and recommend specific mitigation steps—from flood barriers to fire protection upgrades. It’s a proactive model that pays off: FM Global estimates that for every $1 spent on prevention, clients avoid up to $10 in losses.

This kind of risk engineering isn’t limited to industrial campuses anymore. With better data, sensors, and modeling tools, personal and small business insurers can start playing a more active role as well, advising policyholders, flagging vulnerabilities, and helping communities

adapt before disasters strike. Prevention is no longer aspirational. It’s an underused opportunity, and a $50 billion one, by some estimates (Risk & Insurance 2025).

Climate Resilience Building

You know how marathon runners don't just buy fancy shoes and expect to finish the race? They spend months getting their bodies ready for those 26.2 miles. Climate resilience works the same way. As the frequency and severity of disasters rise - Verisk Analytics forecasts that global insured losses from natural catastrophes will average $151 billion annually (going forward), with the potential for even higher losses in particularly severe years (Cueto 2025) - the role of GIS&T in catastrophe modeling, rapid claims assessment, and resilience planning has never been more critical. Advanced geospatial analytics enable insurers to proactively assess exposures, optimize disaster response, and even inform risk mitigation efforts at the community level so that when extreme weather hits, they can take the punch and bounce back.

The challenge is bigger than any single storm or flood. We're talking about systemic risk - the kind that can cascade through an entire community or region. When a major hurricane hits, it's not just about the immediate property damage. It also means power outages affecting hospitals, closed roads blocking emergency services, and business interruptions rippling through the economy.

GIS&T is becoming a vital tool for building this resilience. It helps communities understand what's coming by modeling future climate scenarios. Before disasters strike, it can point out vulnerable infrastructure and show which prevention strategies might work best. Over time, it even helps track whether these resilience measures are working.

Two organizations that get this need to skate toward climate resilience are Ark Venture Studio and the Swiss RE Institute. Ark is tackling systemic risks head-on by building companies that address climate vulnerability, working with an impressive mix of global development organizations, industry leaders, and insurers. Meanwhile, the Swiss RE Institute shares deep risk research and knowledge to drive better decisions, fostering greater resilience across society. Both understand that tomorrow's challenges need new approaches today - whether that's creating new ventures to solve seemingly impossible problems or using forward-looking research to reshape how we think about risk.

In other words, we're moving from being the financial first aid kit after a disaster to being the personal trainer helping communities get stronger before the next big challenge. That's what real resilience looks like.

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