

Quantitative Text-based Shrinking-society Risk Index for Multidimensional Assessment in Coastal Regions

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In this study, the shrinking-society risk index (*SSRI*), utilizing unstructured textual big data to detect and quantify the shrinking-society crisis facing coastal regions in South Korea, is proposed. Recognizing that traditional indicators based on demographic statistics have limitations in the immediate measurement of latent functional degradation within communities, large-scale textual data are defined as environmental and social input signals and a marine soft-sensor framework for multidimensional analysis is designed. The architecture of this framework curated 15 years of news big data and municipal policy documents to perform signal refinement, and was configured to measure social functions through six core parameters: population, economy, healthcare, education, policy response, and social capital. Specifically, in the transducer domain for index derivation, the framework integrates cosine similarity and sentiment analysis algorithms to quantify semantic distances between documents, thereby yielding the functional risk levels of each coastal municipality as quantitative output signals. The experimental results revealed a structural discrepancy between conventional demographic-based risk assessments and the functional risk levels measured by the *SSRI*. Particularly in the coastal regions of Kangwon province, it was confirmed that the policy discourse related to fishery-based livelihoods acts as a buffering signal that delays the intensification of the shrinking-society crisis. These findings suggest that the diagnostic paradigm for shrinking societies must transition from a uniform demographic-centric model to a multidimensional soft-sensing system focused on functional sustainability. This study provide a technical foundation for intelligent monitoring tools in public policy formulation through the presented sophisticated model that diagnoses region-specific vulnerabilities and administrative responsiveness.

1. Introduction

Coastal regions in South Korea are facing a progressively intensifying risk associated with a shrinking society. The aging of the fisheries labor force and the accelerated out-migration of young adults to major metropolitan areas have become pronounced trends, while the number of school closures has rapidly increased.⁽¹⁾ As illustrated in Fig. 1, a substantial number of local

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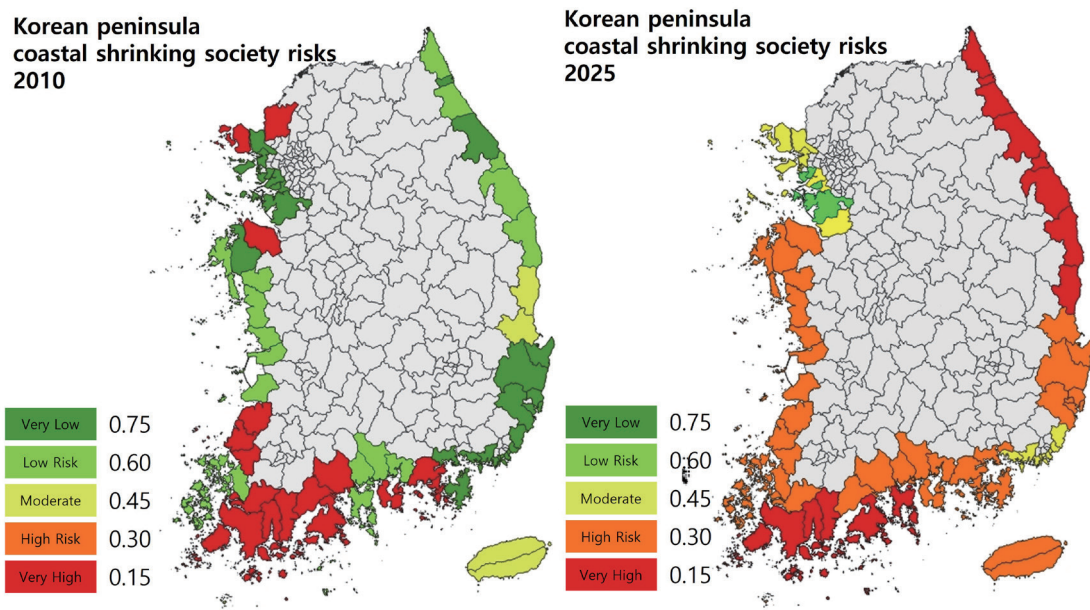


Fig. 1. (Color online) Distributions of shrinking-society risk index in South Korea's coastal regions in 2010 and 2025.

governments have already entered a highly critical stage of social contraction, with structural risks in coastal areas rising annually.⁽²⁾

A fundamental shift is required in the conceptualization of the structural causes of a shrinking society and the corresponding risk-assessment frameworks. While population size and residential settlement were previously regarded as the primary determinants of regional stability, the sustainability of contemporary coastal regions now depends increasingly on relational populations and the intensity of regional utilization.⁽³⁾ Existing studies in both South Korea and Japan indicate that population inflows into non-metropolitan areas are driven by external labor mobility, while the out-migration of younger cohorts continues to exert negative economic pressure on coastal jurisdictions.⁽⁴⁾

This suggests that diagnosing a shrinking society solely through the lens of demographic decline generates a discrepancy between the observed risk conditions and the outcomes of existing assessment models. Prior research has relied predominantly on demographic indicators such as fertility rates, aging ratios, and net migration levels.⁽⁵⁾ While effective in capturing the pace of population reduction, these metrics fail to reflect the deterioration of regional social functions or the efficacy of policy responses. Therefore, a shrinking society must be evaluated not only as a demographic outcome but also through an assessment of how local governments perceive emerging risks and implement countermeasures.

In this context, municipal policy documents and regional reports represent the earliest observable sources reflecting governmental responses. Although local governments annually develop mid- to long-term plans and regional media document social challenges, qualitative interpretation-based studies have yet to evolve into a systematic evaluation model.⁽⁶⁾ Regarding

this gap, a diagnostic framework for coastal shrinking societies using policy-document-based textual similarity analysis is proposed in this study. This methodology applies text-quantification techniques to convert semantic content into vector representations, providing an evaluation model capable of diagnosing shrinking-society conditions through meaning-based information.

2. Literature Review

2.1 Studies on shrinking-society risks in Korean coastal regions

Prior research advanced by diagnosing how rapid demographic shifts weaken community capacity.⁽⁷⁾ Early studies were focused on population decline and the accelerating pace of aging, arguing that a shrinking society emerges when regional sustainability collapses owing to reduced demographic reproduction.⁽⁸⁾ In South Korea, persistent fertility decline and out-migration have led to population thresholds falling below sustainable levels, thereby accelerating these risks.⁽⁹⁾

Demographic studies have quantified local extinction and regional depopulation, demonstrating that simultaneous rises in aging and youth out-migration lead to sequential effects, such as school closures and the contraction of medical infrastructure.^(10–12) As awareness grew that these risks cannot be resolved solely through demographic approaches, research expanded to include regional fiscal capacity and administrative resilience. Municipalities with weak fiscal self-reliance face increasing difficulty in maintaining public services, reinforcing a negative feedback cycle.⁽¹³⁾ This line of research frames shrinking society not merely as a demographic phenomenon but as an outcome linked to vulnerabilities in governance capacity and financial structures. Youth migration has also been identified as a long-term driver of shrinking-society risks in South Korea, stemming from industrial restructuring and labor-supply imbalances. In regions where industrial diversification has not sufficiently progressed beyond manufacturing-based economies, opportunities for young adults diminish, accelerating the shrinking-society trajectory.^(14,15)

Recent scholarship has transitioned toward conceptualizing shrinking-society risks as multilayered phenomena that encompass not only demographic variables but also social and policy-related determinants. Evidence suggests that attenuated community networks and diminished collective activities undermine regional sustainability, indicating that social trust and cooperation exert a systemic influence that extends beyond mere population metrics.⁽¹⁶⁾ Furthermore, research highlights that inter-institutional linkages among local universities, private firms, and municipal governments are critical in shaping youth retention and regional revitalization potential. This academic trajectory reframes the shrinking society as a cumulative erosion of community functions, necessitating solutions that integrate social capital, educational infrastructure, and strategic policy responses.⁽¹⁷⁾

In the South Korean context, the research scope has expanded beyond traditional rural and mountainous locales to encompass small-to-medium cities and coastal regions.⁽¹⁸⁾ In urban centers, the collapse of commercial districts and the obsolescence of aging housing stock have been empirically linked to functional urban decline.⁽¹⁹⁾ Conversely, in coastal regions, industrial

monocultures and climate change have surfaced as potent catalysts for social contraction, while restricted medical access and eroded educational foundations are identified as primary factors compromising long-term residential viability.

Synthetically, these research trajectories indicate that shrinking-society dynamics in South Korea manifest heterogeneously across regional typologies and interacting causal structures. Consequently, the field has progressed from single-indicator diagnostic models toward more sophisticated, differentiated frameworks. This paradigm shift mirrors international trends in Japan and the United States, where the shrinking society is increasingly recognized as a global policy imperative.^(20,21) Cross-national comparative studies continue to investigate the interplay of demographic, industrial, and social determinants, with an emerging body of work focused on evaluating response strategies through integrated and comprehensive assessment models.

2.2 Evaluation model research using text quantification methods

The methodological landscape for diagnosing shrinking-society risks has undergone significant expansion, with recent advancements in text-based quantitative analysis introducing novel possibilities for multidimensional assessment.⁽²²⁾ Unlike conventional studies that rely predominantly on demographic statistics and administrative datasets, emerging research utilizing unstructured textual corpora—such as policy documents, municipal reports, and regional development plans—has demonstrated enhanced analytical rigor.⁽²³⁾ This shift is predicated on the recognition that critical social conditions and institutional responses, which often elude numerical indicators, are intrinsically reflected in the linguistic nuances of national and local policy documentation.⁽²⁴⁾ By examining shifts in linguistic expression and problem recognition within policy processes, contemporary studies aimed at quantifying the lived experience of emerging regional risks.⁽²⁵⁾

In the field of management studies, text-similarity approaches have been successfully applied to evaluate corporate sustainability performance.⁽²⁶⁾ These methodologies facilitate a comparative analysis of strategic directions and response levels by measuring the semantic distance between documents, rather than relying on rudimentary keyword frequencies.⁽²⁷⁾ Representative research utilizing natural language processing (NLP), specifically the Word2Vec algorithm, generates vector-based representations of semantic relationships, thereby enabling the longitudinal tracking of textual evolution within evaluative models.⁽²⁸⁾

The integration of AI-driven analytical tools into research on urban shrinkage and regional sustainability has further broadened the methodological horizon. Word2Vec-based term analysis converts an entire document into vectorized forms, yielding quantitative estimates of document-level similarity.⁽²⁹⁾ This approach effectively mitigates the limitations inherent in traditional qualitative content analysis—such as interpretive subjectivity and restricted scalability—by generating reproducible empirical outputs, thus establishing a clear methodological advantage in text-based research.⁽³⁰⁾

Consequently, text-based quantitative analysis exhibits robust potential to supplement the limitations of conventional statistical methods. In shrinking-society research, latent variables such as social capital, cooperation structures, and administrative capacity have often been

marginalized because of measurement complexities; however, text-analysis techniques enable the extraction and quantification of such critical information. Despite this potential, the application of text-based evaluation models within the South Korean context remains in its nascent stages.⁽³¹⁾ In the present study, semantic similarity analysis and vector-based document comparison are adopted as its methodological cornerstone, and a refined analytical direction for understanding the complex dynamics of shrinking societies in coastal regions is proposed.

3. Research Methodology and Research Design

3.1 Marine soft-sensor framework and shrinking-society risk index (SSRI)

In this study, the marine soft-sensor framework for detecting risks associated with a shrinking society is proposed, utilizing text-based quantitative analysis techniques to facilitate a precise diagnosis within South Korean coastal regions. Within this framework, large-scale unstructured policy and media texts—incorporating the physical and social transformations of communities—serve as input signals for the identification of crisis indicators.

To systematically observe factors unique to fishing communities, such as maritime industrial dependences, healthcare services, educational infrastructure, and social capital, the scope of analysis was confined to 71 primary local government units situated along the coastline. Data collection for these input signals was conducted using BIG KINDS, a South Korean news big data analytics system; the analysis spanned a 15-year period to facilitate the longitudinal observation of time-series trends.

The acquired large-scale raw datasets undergo a preprocessing phase designed to extract substantive patterns. Data within the extensive text repository were restructured in accordance with the 71 coastal municipalities by mapping regional tags and chronological metadata specific to the Korean littoral. Subsequently, through signal preprocessing, articles strictly pertinent to the phenomenon of a shrinking society were isolated. To enhance the precision of the model outcomes, the data were further optimized via a filtering protocol aimed at eliminating redundant entries and extraneous noise unrelated to the shrinking society. The configuration of this signal preprocessing pipeline is illustrated in Fig. 2.

Figure 3 illustrates the core index calculation process of the proposed framework, delineating the systematic procedure for transforming unstructured text into quantitative indices. Part 1 of Fig. 3 represents the initial stage of the framework, specifically the signal refinement process applied to large-scale unstructured textual data. The input signals—comprising local government policy reports, maritime and fishing village development plans, regional revitalization project documents, maritime disaster response records, and media articles—are subjected to rigorous preprocessing. In this phase, the raw text undergoes deduplication, chronological and administrative tagging, stopword removal, lemmatization, and morphological tokenization. Through these procedures, the initial unstructured data is converted into an optimized input dataset compatible with the analytical algorithms.

Part 2 of Fig. 3 shows the construction of a domain-specific shrinking-society lexicon based on NLP, categorized into six critical dimensions: population, economy, healthcare, education,

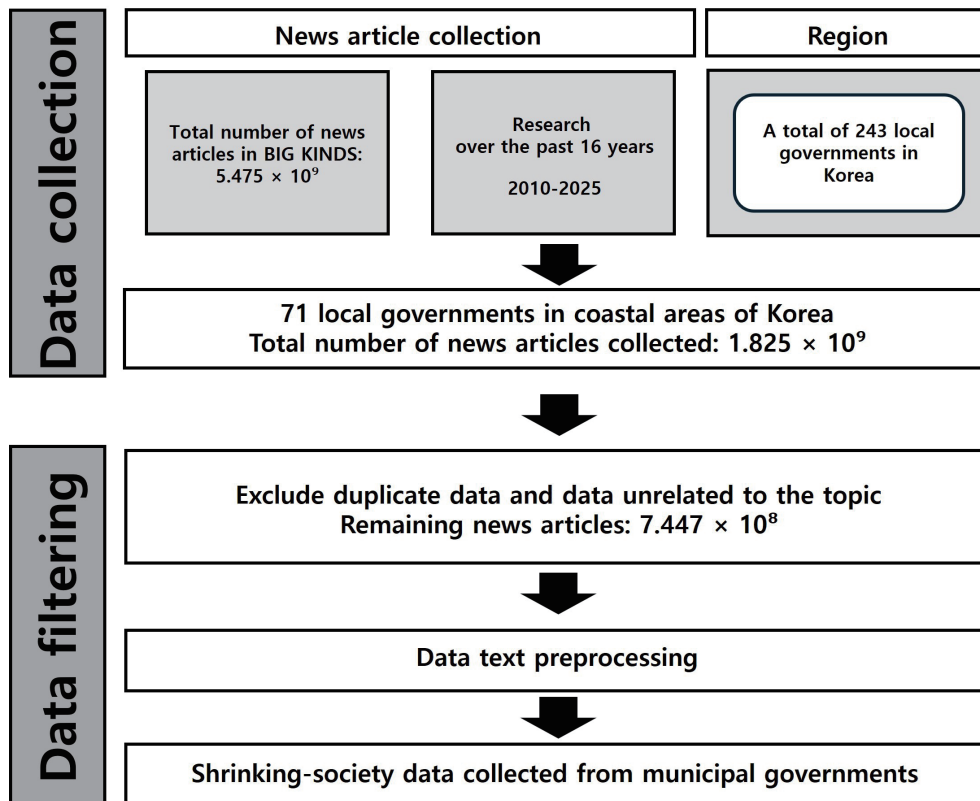


Fig. 2. Collecting data on shrinking-society risk response in Korea's municipal region.

policy response, and social capital. This lexicon deviates from a reliance on rudimentary metrics—such as the simple depopulation rates typically found in conventional research—by integrally reflecting the structural vulnerabilities of coastal regions. This includes functional descriptions of healthcare and educational sustainability, the efficacy of policy responses, and shifts in social connectivity. This approach incorporates contemporary research perspectives that define shrinking-society risks within the South Korean context directly into the lexicon construction process.

Part 3 of Fig. 3 represents a transducer that maps the established lexicon and the preprocessed input data into quantitative values within a multidimensional vector space. The framework calculates the degree of alignment with the shrinking-society phenomenon by measuring the semantic distance between document and lexicon vectors using cosine similarity. A similarity value approaching 1.0 indicates a high level of semantic congruence between the regional documentation and the representative lexicon, signifying a robust formation of discourse and policy responses regarding the shrinking society within that jurisdiction.

Consequently, the semantic-similarity-based values derived from the transducer are yielded as the *SSRI*, which functions as the final output signal. This index provides a comprehensive

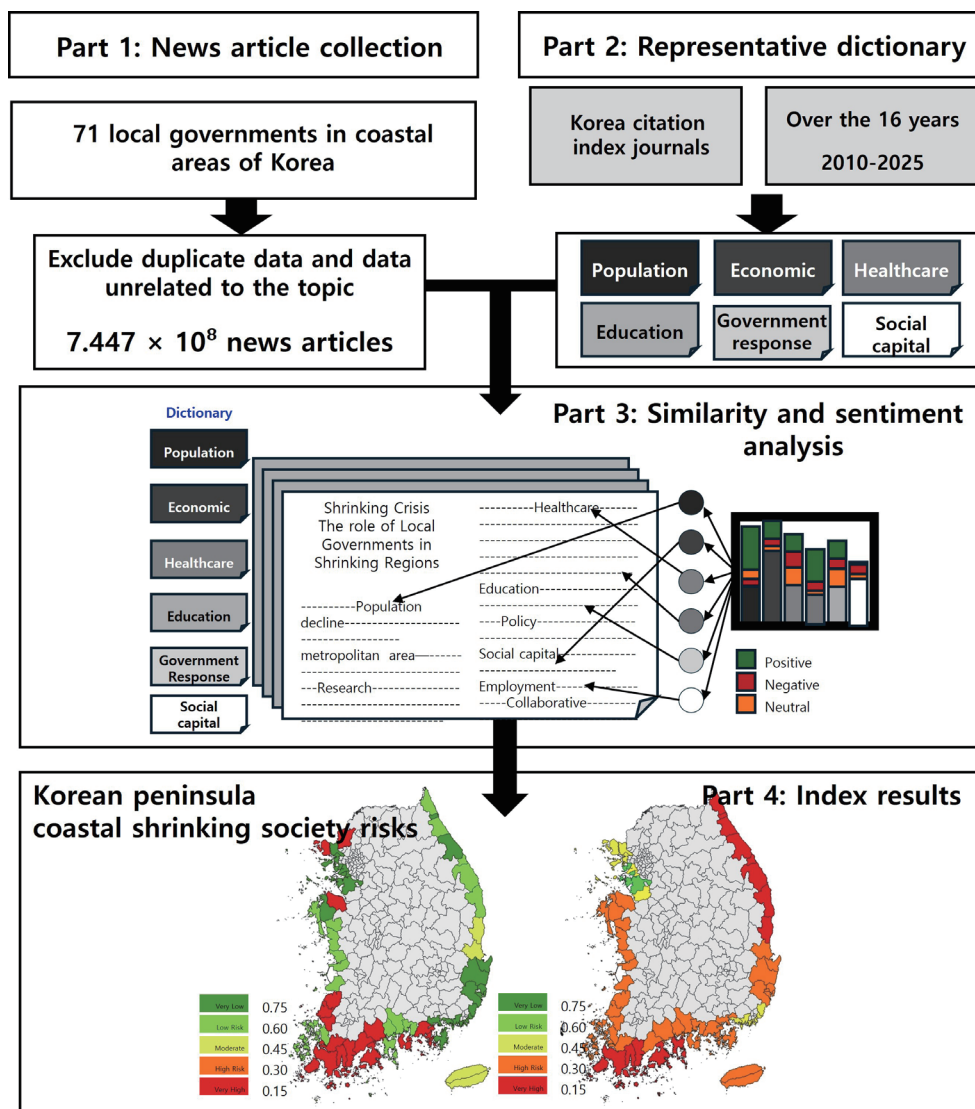


Fig. 3. (Color online) Framework for shrinking-society risk index.

representation of both the severity of structural crises and the level of policy responsiveness for each coastal municipality. By comparing the annual index values within a specific timeframe, the trajectory of crisis-level fluctuations can be effectively tracked.

Part 4 of Fig. 3 presents the terminal output, which visualizes the disparities in structural vulnerabilities through inter-regional comparisons. The explicit construction of this marine soft-sensor framework for detecting shrinking-society risks provides a sophisticated diagnostic tool capable of quantifying the latent risk factors of communities in real time by leveraging unstructured linguistic data.

3.2 Preprocessing for lexicon to detect shrinking-society risks

A representative lexicon construction procedure, which serves as the computational core of the text-quantification algorithm for analyzing shrinking societies in coastal regions, was executed. To accurately reflect the longitudinal expansion of academic discourse regarding shrinking societies and regional extinction, the scope of data collection was restricted to Korea citation index journals and related academic publications in South Korea issued between January 2010 and September 2025. As illustrated in Fig. 4, the search keywords—including ‘shrinking society’, ‘local extinction’, ‘regional extinction’, and ‘population extinction’—were cross-referenced, yielding an initial pool of 279 documents.

The raw academic texts were first subjected to an automated deduplication algorithm to exclude documents with identical digital object identifiers and bibliographic metadata. Subsequently, literature with insufficient direct relevance to the shrinking-society phenomenon was eliminated through a theme-based filtering protocol. Following this refinement, the final analytical dataset was established at 239 documents. This preemptive removal of inconsistent data and thematic noise was essential to prevent the propagation of semantic errors during the subsequent morphological analysis and lexicon construction phases.

In the text preprocessing phase for the finalized literature, word-level tokens were generated using an NLP-based morphological analyzer. To enhance analytical clarity, stopwords—such as particles and conjunctions with minimal contextual contribution—were comprehensively removed, and core vocabulary was extracted by applying part-of-speech filtering focused on nouns. All extracted terms underwent lemmatization to consolidate various inflections into a single base form. The preprocessed text was then merged into a unified corpus, serving as the input for the lexicon construction algorithms.

The initial stage of lexicon generation was conducted using term frequency (TF)–inverse document frequency (IDF)-based frequency extraction. TF was calculated on the basis of intra-document occurrence, while IDF was computed using the logarithmic ratio of corpus-wide distribution. Terms within the top 10th percentile of TF–IDF composite scores were retained. The second stage involved constructing a Word2Vec model to facilitate semantic expansion beyond frequency-driven selection, enabling the identification of terms that perform meaningful functional roles within shrinking-society discourse.

The entire preprocessed corpus served as the model input, utilizing the skip-gram architecture. Prior studies indicate that the skip-gram model outperforms the continuous bag-of-words approach when appropriate hyperparameter tuning is implemented.⁽³²⁾ On the basis of these findings, the embedding dimension was set to 200, balancing semantic discrimination with computational efficiency.⁽³³⁾ The window size was fixed at five to constrain the contextual scope, and the minimum frequency threshold was set at five to eliminate noise terms. The model was trained for 20 epochs using negative sampling with five negative samples.

As a result of the Word2Vec modeling process, semantically co-occurring terms not detected through the TF–IDF threshold were additionally identified. This procedure supplements low-frequency but contextually significant vocabulary by analyzing semantic proximity, thereby integrating frequency-based importance with structural semantic information. The final output functions as an optimized term set that most effectively represents the conceptual characteristics of shrinking-society phenomena.

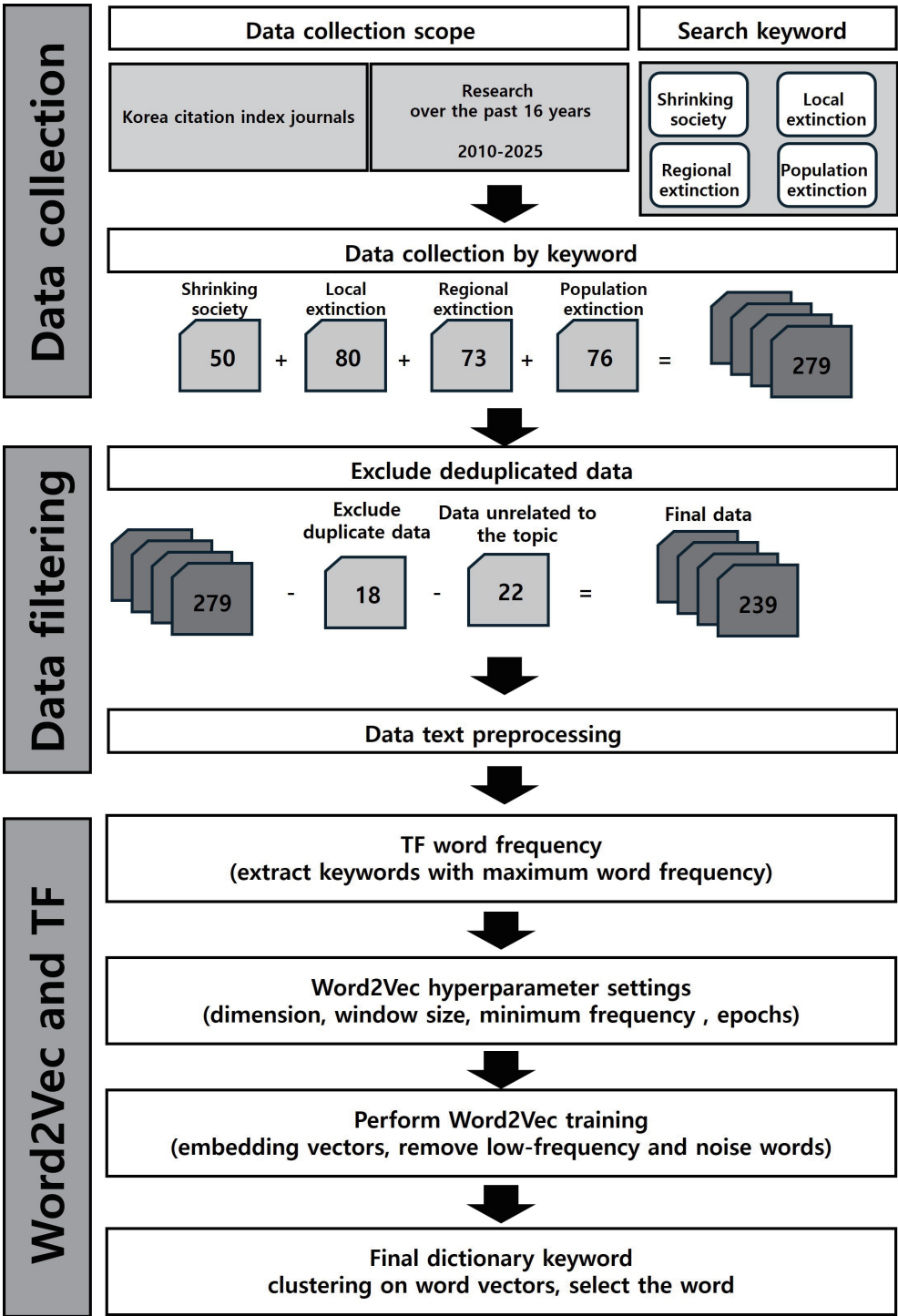


Fig. 4. Framework for lexicon of SSRI.

3.3 Index calculation within the transducer domain for the *SSRI*

Within the proposed marine soft-sensor framework, the pivotal mechanism for converting unstructured textual signals into quantitative risk indices is based on a transducer algorithm. The comparative document analysis performed within the transducer utilizes cosine similarity to precisely quantify the semantic distance between texts in a multidimensional vector space, subsequently integrating the polarity of the documents to generate the *SSRI*.

A significant methodological challenge in comparing regional policy documents and media articles is the extreme variance in total text volume and absolute document length across different municipalities. To prevent these disparities from acting as noise that could skew the index calculation, the transducer in this study adopts cosine similarity—which is invariant to vector magnitude—rather than Euclidean distance. The calculation is defined as

$$SSRI(A, B) = \left(\frac{\sum_{i=1}^n A_i B_i}{\sqrt{\sum_{i=1}^n A_i^2} \sqrt{\sum_{i=1}^n B_i^2}} \right) \times Polarity(A). \quad (1)$$

In this context, A represents the document unit vector of an individual municipality and B represents the lexicon vector. By dividing the dot product of the vectors by the product of their magnitudes, the transducer mathematically normalizes the absolute length of the documents. This ensures that the resulting similarity values strictly reflect pure semantic alignment and vector directionality, effectively eliminating the noise inherent in varying text volumes.

Furthermore, to ensure the integrity of the semantic interpretation, the transducer model integrates a diagnostic system that accounts for the polarity orientation of the language. This is necessitated by the fact that even if agenda salience (as derived via cosine similarity) is identical, the implications of the index differ significantly depending on the semantic direction of the discourse. For instance, frequent mentions of terms, such as healthcare blind spots and school closures, resulting in high similarity values should not be misinterpreted solely as an indication of physical vulnerability.

Consequently, sentiment analysis was conducted to discern whether the extracted signals represent warning signals reporting crisis symptoms (negative polarity) or response signals proposing policy alternatives (positive polarity). The *SSRI* calculated through this integrated formula performs the following diagnostic functions.

In this framework, when high similarity is coupled with negative (−) polarity, it is interpreted as a signal that the actual severity of the crisis has reached a critical threshold. Conversely, when high similarity is coupled with positive (+) polarity, it signifies that administrative responses and discourse formation regarding the crisis are functioning effectively. This indicates a robust manifestation of administrative responsiveness by local governments to set the crisis as a public agenda and seek resolutions. As such, the index serves as a metric for how sensitively a community institutionally senses and reacts to inherent social risks.

Ultimately, the indices derived from this framework provide a multidimensional reflection of the latent social risks within a community across six core domains: population, economy, healthcare, education, policy response, and social capital. By incorporating contextual nuances and linguistic attitudes into vector operations—beyond rudimentary term frequencies—the marine soft-sensor functions as a mechanism capable of simultaneously diagnosing the nature of the crisis and the efficacy of the corresponding policies, as illustrated in Fig. 5.

4. Results

4.1 Lexicon for the SSRI

The representative lexicon developed in this study was designed to extract the functional status of coastal regions in a quantifiable manner. Within the population domain, key terms such as population, aging, youth migration, net migration, intensified outflow, and fertility emerged as primary candidates. In the economic domain, terms including regional economic contraction, job, industrial base, commercial district, the depletion of marine resources, and economic vitality exhibited high distinctiveness.

The TF-IDF-based term extraction was supplemented through semantic expansion using Word2Vec to capture contextual associations that frequency-based filtering alone might fail to identify. Word2Vec was employed to generate vector representations for each candidate term, after which semantically proximate neighboring words were identified on the basis of cosine similarity. For instance, in proximity to population terms such as youth population, shrinking school-age population, and single-person households were closely clustered. Regarding medical service, the identified clusters included hospitals, emergency care, and the shortage of medical

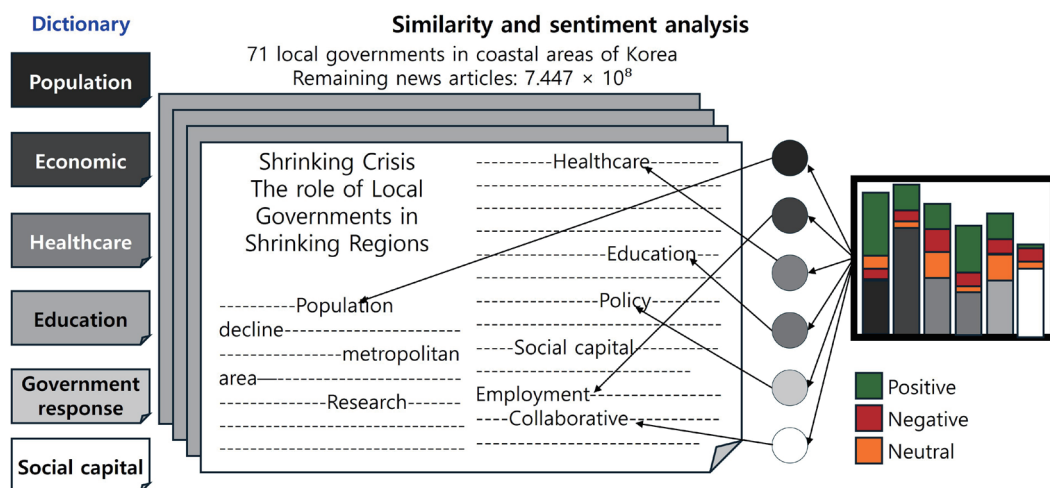


Fig. 5. (Color online) Schematic diagram of index calculation method using similarity and sentiment analysis.

and healthcare accessibility. This expansion phase effectively compensated for terms that were excluded under TF-IDF criteria but appeared recurrently in textual descriptions of shrinking-society conditions.

In the economic domain, additional terms such as fisheries infrastructure, rising commercial closures, business attraction, and fiscal self-reliance were incorporated. The healthcare domain included medical service, emergency transport, maternity care, and healthcare, demonstrating a concentration of accessibility-related expressions. In the education domain, school, class, commuting distance, and the educational infrastructure emerged as core indicators. The policy domain encompassed support systems, incomplete policy implementation, budgetary, and policy coordination at the regional level. Finally, the social-capital domain was characterized by community, resident cohesion, social isolation, and cooperative networks. Overall, the constructed lexicon functions not as a simple keyword list but as a structured reference set that reflects the functional processes inherent to shrinking-society phenomena. This demonstrates its analytical utility in capturing the multidimensional vulnerability of coastal regions, as summarized in Table 1.

Table 1
Lexicon of shrinking-society risk.

Population	Economy	Healthcare	Education	Policy	Social Capital
population decline	economic contraction	healthcare	school	policy execution	community
population reduction	economic activity	medical shortage	branch school	policy effect	resident bond
shrinking risk	job loss	hospital absence	student	support system	social trust
aging	employment	medical personnel	class reduction	long-term plan	disconnection
youth out-migration	youth job	physician	teacher supply	plan implementation	neighbor interaction
youth decline	income level	nursing staff	teacher recruitment	budget	social isolation
child decrease	income gap	emergency care	school-age population	financial support	mutual support
school-age population	industry	emergency transport	youth educational	business risk	self-help group
fertility	fishing industry	delivery region	basic academic	upward planning	volunteer
fertility rate	fishery resource	medical accessibility	educational infrastructure	data absence	community center
net out-migration	self-employed	long-distance treatment travel	remote learning dependence	statistical insufficiency	shared space
migration increase	commercial district	visiting care	after-school education	governance shortage	resident participation
immigration stagnation	store increase	chronic disease	commuting distance	departmental cooperation	youth group

4.2 Comparison of *SSRI* and local extinction index (*LEI*)

The *SSRI* derived in this study shares a partial statistical trajectory with the conventional *LEI* provided by the Korea Employment Information Service; however, significant disparities manifest in their specific values and trends. Comparative analysis reveals that while the *LEI* tends to exhibit a precipitous decline following a specific tipping point, the *SSRI* proposed in this study demonstrates a relatively moderate and cumulative reduction. This divergence suggests that the crisis in coastal regions cannot be elucidated solely by short-term demographic fluctuations; rather, it manifests through a long-term, incremental process of weakening essential regional functions, including the economy, healthcare, and education.

In the index calculation for coastal municipalities, maritime-specific discourse—which distinguishes these areas from inland regions—exerted a decisive influence. Within the proposed marine soft-sensor framework, textual signals such as the extinction of fishing villages, productivity decline due to maritime resource fluctuations, and the aging of the youth fishing population functioned with high semantic weights. For example, while certain high-risk coastal areas in Jeollanam-do and Kangwon-do recorded demographic declines similar to those in inland regions, the textual analysis revealed a densely formed administrative discourse regarding the dissolution of fishery structures. This provided a defensive effect in the *SSRI* results, empirically demonstrating that the crisis detection sensors for coastal areas operate through a signal system and weighting mechanism qualitatively distinct from the rural extinction models applied to inland areas.

These discrepancies arise fundamentally from the differing variables utilized in each index. The *LEI* focuses on reproducible demographic structures, such as fertility rates and the net migration of the youth population, specializing in the sensitive detection of early demographic warning signs. In contrast, the *SSRI* quantifies a complex array of multidimensional functional factors, including healthcare accessibility, the sustainability of educational infrastructure, the continuity of economic activities, the frequency of governmental crisis-response documentation, and social connectivity. This allows for the detection of the cumulative intensification of crises.

Consequently, a significant structural time lag was identified between the points at which the respective indices decline. This implies that primary demographic risks do not immediately translate into functional risks for the community. In certain regions, essential functional degradation may be delayed owing to social capital or administrative capacity, despite a decrease in population. Regional comparative analysis across South Korean metropolitan jurisdictions further underscores these characteristics. As shown in Fig. 6, the shrinking-society risk analysis results were compared with the local extinction index to identify differences in the temporal and regional patterns of shrinking-society risk.

In the coastal regions of Kangwon-do, a progressive convergence between the two indices has been discernible since 2015. Notably, the decline observed in 2025 was more pronounced than in other jurisdictions. This phenomenon can be interpreted as a sequential manifestation, where primary demographic shocks are followed by the subsequent intensification of functional vulnerabilities, such as healthcare voids and heightened exposure to coastal disasters.

Both Jeollanam-do and Jeollabuk-do regions exhibited comparable downward trends, displaying distinct variances in the gradient of their decline. Notwithstanding their shared trajectory of protracted industrial weakening, the *LEI* recorded a sharp contraction, whereas the *SSRI* manifested a more gradual attrition attributed to the sustained formation of administrative discourse. This divergence corroborates the premise that functional risks emerge as cumulative structural processes over time, rather than as abrupt, isolated shocks.

Gyeongsangbuk-do and Gyeongsangnam-do regions exhibited a relatively marginal decline characterized by statistically significant periods of index stagnation. The analysis results suggest that robust interconnections with inland industrial clusters and diversified economic activities functioned as an attenuating buffer against coastal-specific vulnerabilities. Notably, certain municipalities remained stable within the proposed framework despite being classified as high-risk by the *LEI*, thereby validating functional diagnosis as a non-tautological metric that transcends simple demographic indicators.

Throughout the analysis period, Chungcheongnam-do and Gyeonggi-do regions maintained the highest relative stability and the most attenuated rates of decline. In particular, the western coast of Gyeonggi-do exhibited a significant latency in crisis intensification. This is largely attributable to its robust structural stability, which is contingent upon integrated commuting networks and functional linkages with the Seoul Metropolitan Area.

The paramount implication of this comparative analysis lies in the identification of a temporal lag in risk transition and the existence of distinct structural typologies of risk development across regions. While the *LEI* acts as an early warning indicator for the rapid onset of demographic risk, the *SSRI* provides a multidimensional, ex-post diagnosis of the cumulative

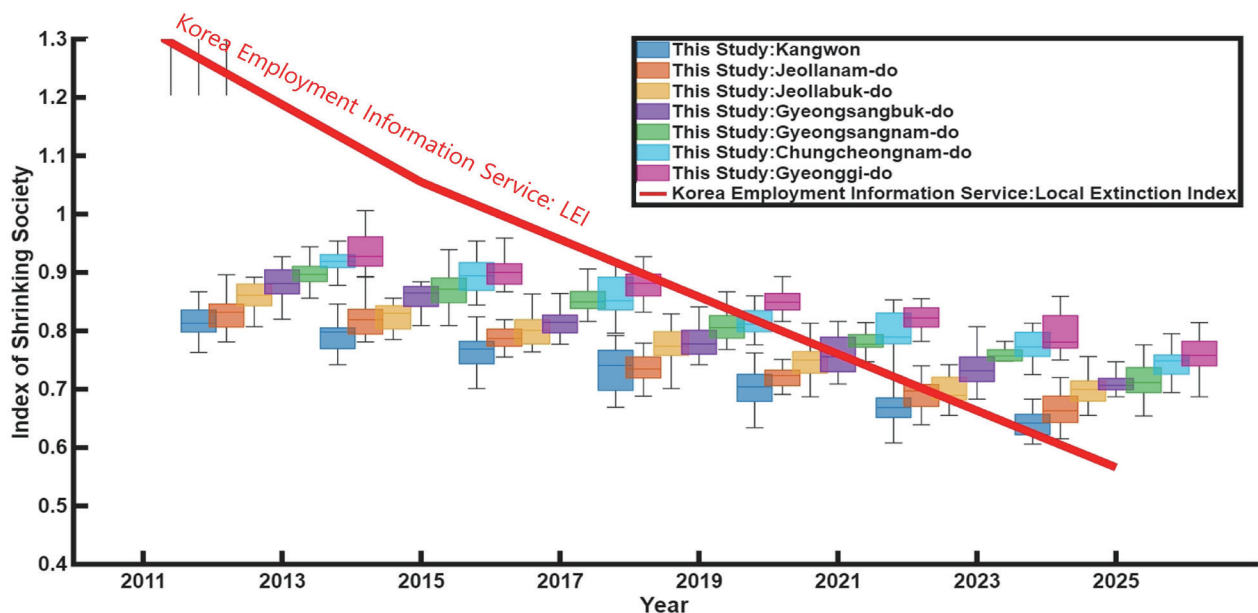


Fig. 6. (Color online) Shrinking-society risk analysis results and the local extinction index.

structural erosion of essential community functions. This complementary dual-diagnosis system strongly suggests that a singular indicator is insufficient to fully interpret the multifaceted crisis stages of a region. Ultimately, these findings necessitate the adoption of more sophisticated and differentiated criteria for determining the timing and priorities of policy interventions. This research provides empirical evidence that diagnosing extinction risks in coastal South Korea must incorporate metrics for functional sustainability to supplement traditional demographic statistics.

5. Conclusions and Implications

In this study, a novel index, the *SSRI*, was proposed to quantify shrinking-society risks by text-based quantitative analysis to coastal regions in South Korea. While conventional research on local extinction has primarily focused on the early detection of risk transition points through demographic decline indicators, in this study, the marine soft-sensor framework designed to structurally comprehend the process of functional deterioration that ensues following population loss was established. To this end, articles and policy documents spanning a 16-year period were curated, and a representative lexicon was constructed by integrating TF-IDF-based key term extraction with Word2Vec-based semantic space modeling. Subsequently, the level of functional weakening for each coastal municipality was quantified by calculating the semantic distance between document and lexicon vectors using cosine similarity.

The *SSRI* derived through this framework measures the frequency and semantic density of discourses related to shrinking societies within public textual domains. It identifies whether a municipality recognizes the shrinking-society crisis as a significant public agenda and evaluates the necessity for active responses across six core dimensions: population, economy, healthcare, education, policy response, and social capital. The results indicated that the *SSRI* manifests a more attenuated rate of decline compared with the *LEI* provided by the Korea Employment Information Service.^(34,35) This finding is interpreted as evidence confirming that function-based risks intensify as a post-hoc phenomenon following population-based risks. While risk levels expanded rapidly in Kangwon-do and Jeollanam-do, coastal areas in Gyeonggi-do and Chungcheongnam-do exhibited a relatively stable distribution owing to structural buffer effects.⁽³⁶⁾ Such disparities empirically demonstrate that coastal risks are not driven by a single variable but unfold through a complex interplay of healthcare accessibility, mobility constraints, industrial vulnerability, and the contraction of public services.⁽³⁷⁾

The findings of this study clearly reflect the structural characteristics unique to coastal municipalities, which are distinctly differentiated from the rural extinction patterns observed in inland areas. While inland crises are predominantly explained by the collapse of agricultural foundations or urban hollowing, coastal regions follow a specific trajectory involving the weakening of fishery-based livelihoods, the rapid depletion of marine resources, and the physical dissolution of fishing communities. Within the marine soft-sensor framework, these coastal-specific keywords functioned as powerful input signals beyond mere frequency. For instance, policy documents in the coastal regions of Jeollanam-do and Kangwon-do exhibited a high

density of discourse regarding income loss due to marine resource depletion and the exodus of young fishers and vessel reduction. These signals acted as primary drivers in narrowing the semantic distance to the representative lexicon within the transducer. In fact, it was confirmed that the specialized keyword group related to the decline of fisheries and marine resources was assigned significant semantic weights in the final risk index calculation compared with other inland-related factors.

This evidence proves that in coastal municipalities—where multiple crises such as climate-induced ecosystem shifts and the collapse of the fisheries industry converge—policy anxiety and administrative demands are expressed far more explosively in text, even when compared with other depopulating regions. Ultimately, the marine soft-sensor framework succeeded in precisely measuring the multidimensional crisis structure of coastal areas that uniform demographic statistics fail to capture. The results of this study reaffirm that shrinking-society issues in coastal regions cannot be fully grasped through population data alone and highlights the urgent necessity for function-based and region-specific diagnostics.

The implications of this research strongly suggest that the response system for local extinction must transition from a population-indicator-centric judgment structure to a multidimensional diagnostic framework centered on functional sustainability. In coastal regions, the accumulation of healthcare voids, weakening educational infrastructure, and the loss of fishery foundations following initial population decline lead to a risk acceleration phenomenon.⁽³⁸⁾ This implies that short-term migration incentives or uniform population attraction projects are insufficient to mitigate deeply entrenched structural vulnerabilities. Furthermore, the observed regional variations in index distribution confirm that the causes and speeds of risk development differ even among coastal areas. Therefore, rather than a uniform national response, differentiated and tailored interventions based on specific regional vulnerabilities and administrative responsiveness are required.⁽³⁹⁾

In future research, the predictability of risk transition points could be markedly increased by quantitatively analyzing the time lag between the *SSRI* and traditional demographic indicators. It is also necessary to subdivide regional semantic spaces through cluster analysis to derive various typologies of coastal-type shrinking societies, taking into consideration the potential existence of different risk groups based on industrial structures and mobility conditions. Despite limitations in the data collection scope, this study demonstrated that establishing a real-time update system for textual data can enable the expansion of models that continuously analyze the dynamic relationship between policy shifts and crisis signals. In the long term, it is necessary to actively review the standardization and international applicability of the shrinking-society diagnostic system by expanding this analytical structure and framework to global coastal regions for cross-national comparative studies.

Acknowledgments

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