AI IN THE SERVICE OF RETIREMENT:

BRIDGING PREDICTION WITH INTERPRETABILITY

BY **GEORGIOS SYMEONIDIS**

As demographic shifts pressure EU Member States to strengthen the funded pillars of their pension systems, the need for accurate replacement rate estimation has become critical. A new study proposes a hybrid path, combining the raw power of Deep Learning with the transparency of Fuzzy Logic.

This article has been based on a paper. See end of article for details.

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Maintaining a standard of living after retirement depends directly on the replacement rate, frequently calculated as the fraction of the first pension amount over the last wage. In an environment characterized by economic uncertainty and incomplete data, traditional deterministic formulas often struggle to incorporate the complexity of modern financial landscapes and the qualitative insights of industry experts.

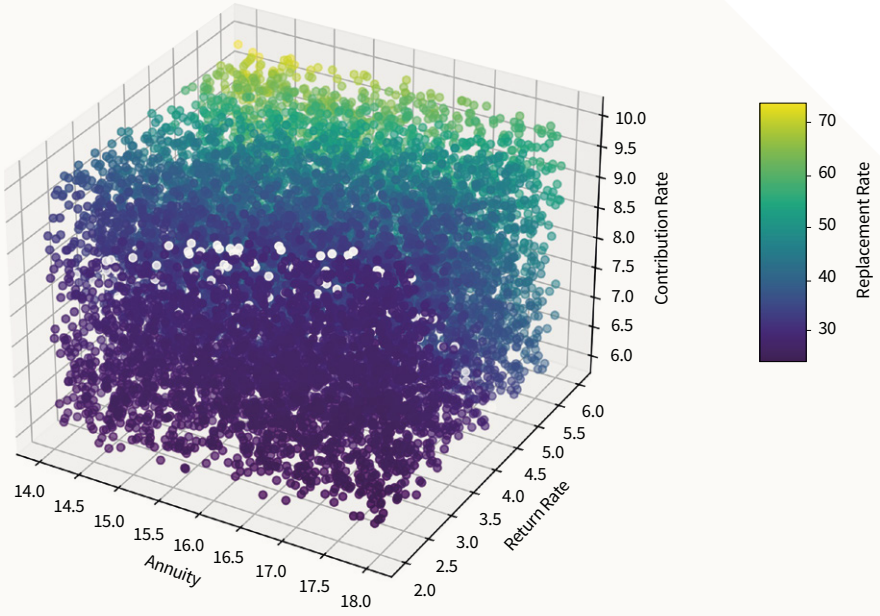
TWO WORLDS, ONE OBJECTIVE

The research evaluated two distinct Artificial Intelligence (AI) methodologies using an extensive synthetic dataset of 500,000 samples, simulating realistic pension planning scenarios based on variables such as annuity values, contribution rates, and investment returns. >

1. **Artificial Neural Networks (ANN):** The deep learning model demonstrated remarkable precision, especially when fine-tuned after a few, less successful, initial efforts. Its ability to identify intricate, non-linear patterns makes it an ideal candidate for large-scale data analysis in pension fund management.

FIGURE 1: Optimized Artificial Neural Network (ANN) Replacement Rate Values

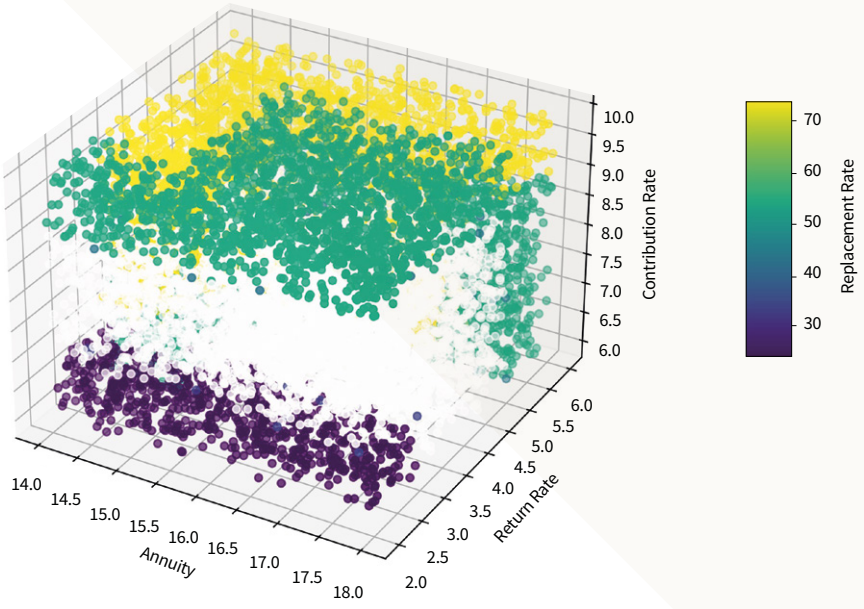
3D Plot with Replacement Rate Color Coding



2. **Mamdani Fuzzy Inference System (FIS):** Unlike the 'black-box' nature of neural networks, the FIS approach is rule-based, mirrors human reasoning and requires expert judgement (e.g., 'If annuity is high and return rate is low, then replacement rate is medium'). While it showed higher fluctuations in predictions compared to ANNs, it offers unparalleled interpretability and transparency. >

FIGURE 2: Optimized Fuzzy Inference System (FIS) Replacement Rate Values

3D Plot with Replacement Rate Color Coding



THE SOLUTION: MULTI-CRITERIA INTEGRATION (AHP)

To bridge the gap between quantitative power and qualitative transparency, the authors recommend the approach of the **Analytic Hierarchy Process (AHP)**. This structured decision-making framework allows actuaries and fund managers to systematically weigh different modeling paradigms based on several key criteria:

- **Accuracy:** Prioritizing the precision of the ANN.
- **Interpretability:** Leveraging the rule-based clarity of the FIS.
- **Stability:** Ensuring consistent outputs under input perturbations.
- **Computational Cost:** Balancing resources against performance.

In this hybrid framework, the ANN provides the predictive 'heavy lifting' while the FIS ensures that the underlying logic is explainable to stakeholders and regulators.

STRATEGIC IMPLICATIONS

For European insurers and pension providers, integrating such AI-driven tools offers a scalable way to process large datasets with minimal human intervention while maintaining the ability to integrate expert knowledge where necessary. Furthermore, the use of explainability tools like SHAP or LIME alongside these models can foster the trust and transparency required for regulatory compliance and stakeholder confidence.

Ultimately, recognizing when to rely on a neural network's precision and when to prioritize a fuzzy system's reasoning may be one of the most valuable contributions AI can make to modern pension governance.

GEORGIOS SYMEONIDIS is an actuarial consultant working mainly in the field of pensions. He holds a PhD in Insurance Economics and is a fully qualified Actuary. He is the Chair of the International Association of Consulting Actuaries (IACA), Section of the International Actuarial Association (IAA), and a member of the Strategic Planning Committee (SPC) of the IAA.

This article is based on the paper **'Introducing AI in Pension Planning: A Comparative Study of Deep Learning and Mamdani Fuzzy Inference Systems for Estimating Replacement Rates'** by Pantelis Z. Lappas and Georgios Symeonidis, published in 'Mathematics' in November 2025. An early version of the paper was submitted to the 1st Joint Colloquium of the Sections of the IAA hosted in Belgium in September 2024. The authors received the Best Paper Award by the Pension Benefits and Social Security Section. <