

# **MODELING FUTURE WORKFORCES: A SYSTEMS-AGENT SIMULATION APPROACH**

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# The Problem

# The Strategic HR Management Problem: System Feedback

As traditional HR managers make the transition to becoming true business partners, their greatest single challenge is ...

... the need to appreciate “powerful connections” and “deadly combinations” presented by feedback structures.

(Source: Becker et al., “HR as a source of shareholder value” *HRM*)

# Feedback Example: Pension Reduction

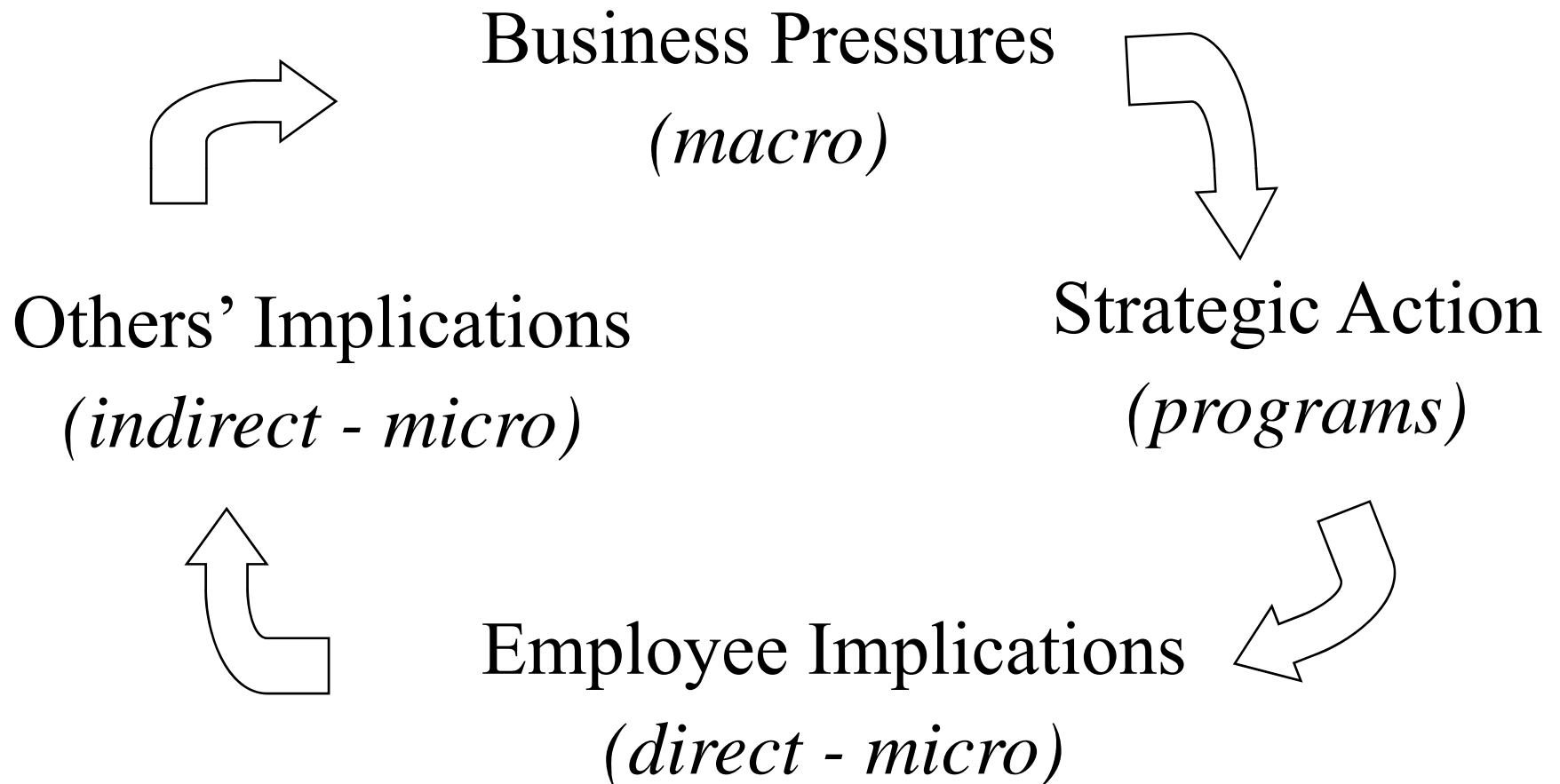
An unintended consequence of reducing pension benefits could be the "unraveling" of the workforce. For example:

- increased turnover
- difficulty in attracting new hires
- possibility of union organizing activity

These developments (and other less obvious ones) could seriously impact the employer's ability to meet business and financial objectives.

(Source: one of 10 interviewed HR senior executives)

# The underlying Feedback model



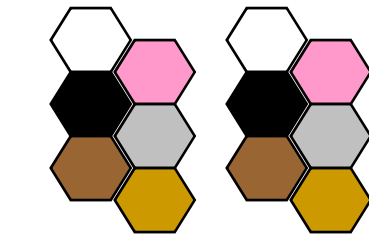
# Agents -- and Employee Demographics

- Increasingly, employers pay attention to diverse demographics, whether “embracing diversity” or complying with government mandates.
- Individuals’ demographics, relationships and statuses all are relevant at micro-level in HR management.
- There is no average, “representative” individual.

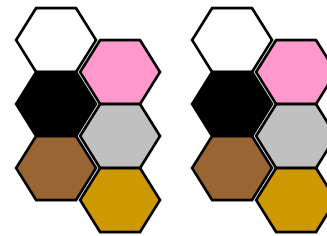
# The “Representative” Individual



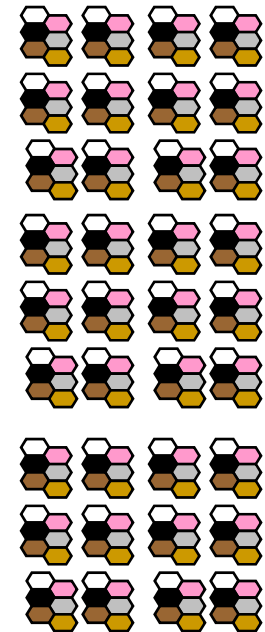
Gender  
& Race  
(6 types)



Add Retirement  
Eligibility  
(12 types)



Add Org.  
Level  
(36 types)



(No real  
limit...)

There's no “representative” individual. Micro level tracking must complement the macro “strategic” view. (Kirman, 1992)

# A Combination of Simulation Methods

To reveal feedback AND avoid simplistic assumptions about “average” individuals, we combine two simulation methods:

- **System Dynamics** permits the study of the behavior of systems of interrelated elements. We use SD components to represent strategic- or program-level concerns.
- **Agent Based Modeling** employs software ‘agents’ to mimic the behaviors and characteristics of individual employees. We use ABM components to reveal unpredictable consequences of individual interactions.

# Combination Through Hybrid Multi-level architecture

- SD software (Vensim) is used to model behavior at organizational and program levels.
- Proprietary heterogeneous agent modeling (“HAM”) software is used at the individual level.
- Heterogeneous employee “agents” are modeled as arrays of attributes and embedded in the SD environment.

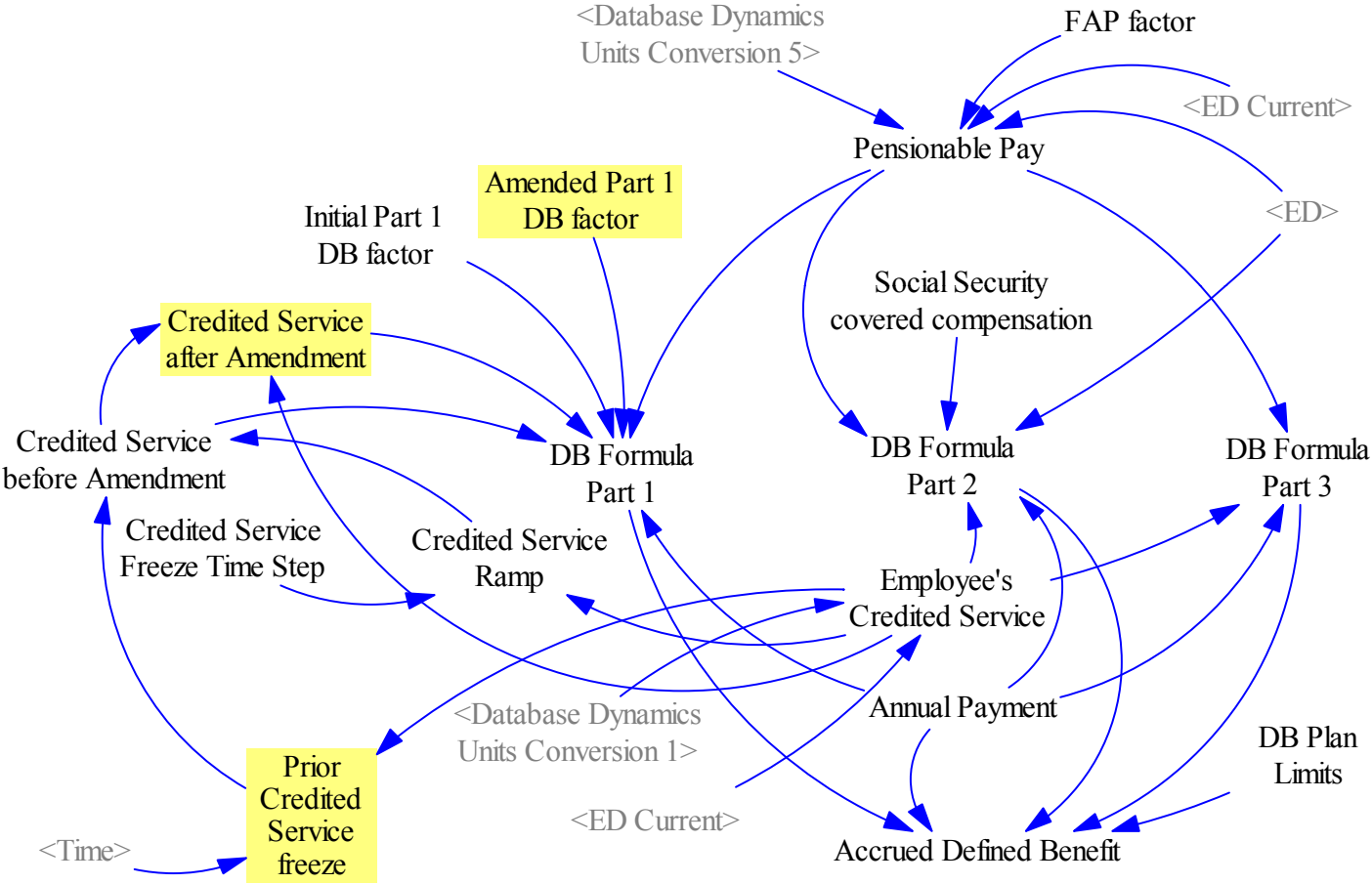
## Example: Employees as Arrays of Attributes

- Within the database, each applicant, retiree and employee exists as a string variable or row.
- Each variable is subscripted for non-stock, non-flow properties like race, gender, department, date of hire, employee status, etc.
- In the following sample model diagrams, individual data like Current Pay, Credited Service and others are created and updated within an umbrella SD environment.

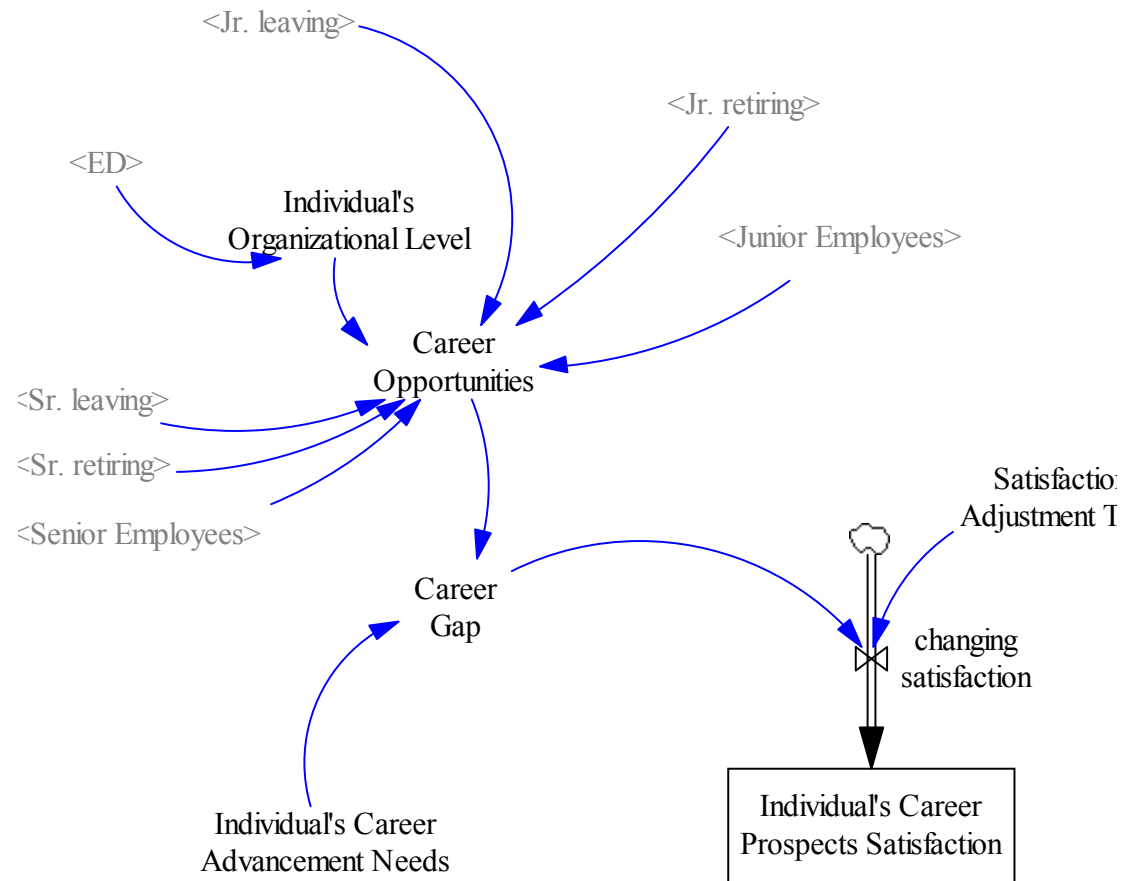
# Hybrid, Multi-Level Architecture (3 levels of analysis)

- The firm
- HR programs and decision-making
- Employees (past, present, future)

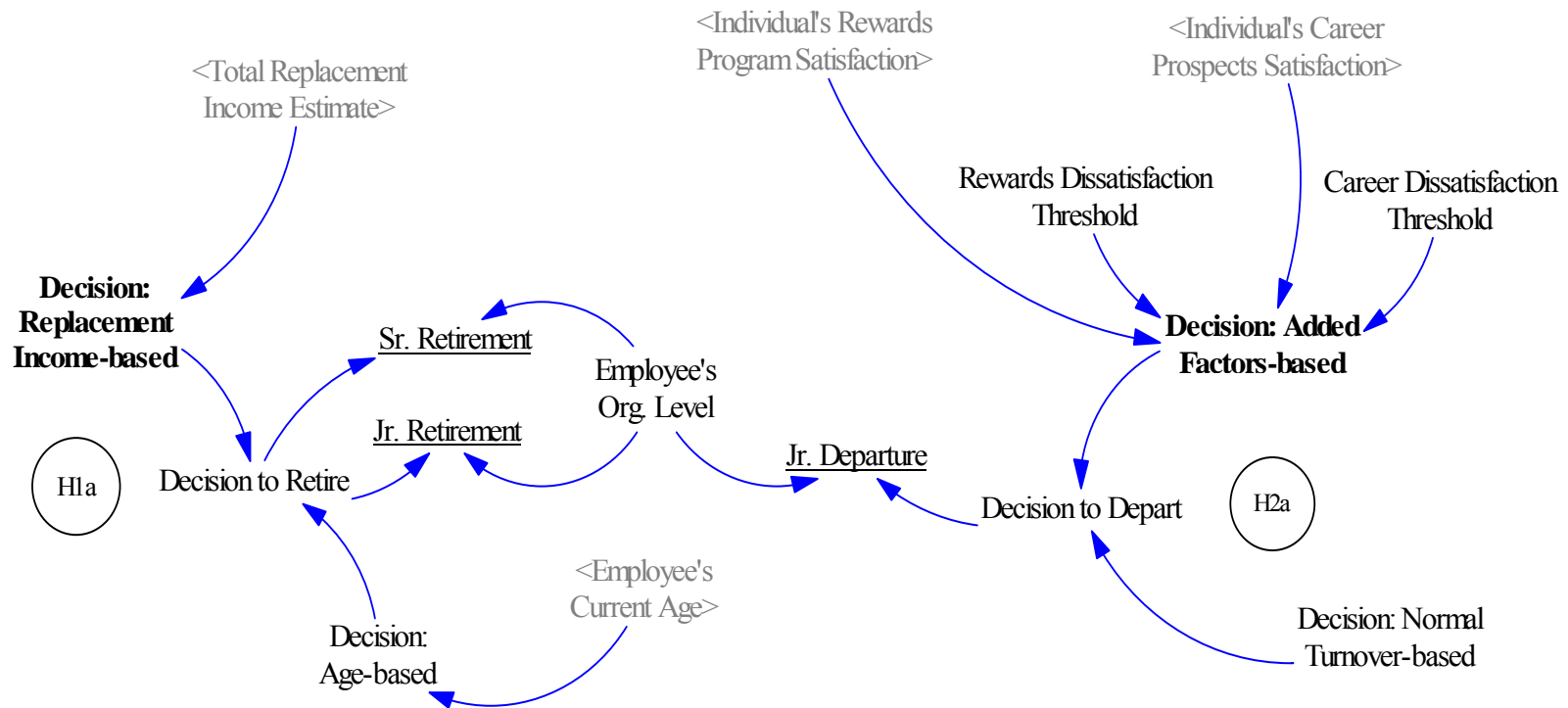
# Program Level: Retirement Income Calculations Altered by SHRM Decision



# Individual Level: Seniors' Retirements Influence Juniors' Prospects and Satisfaction

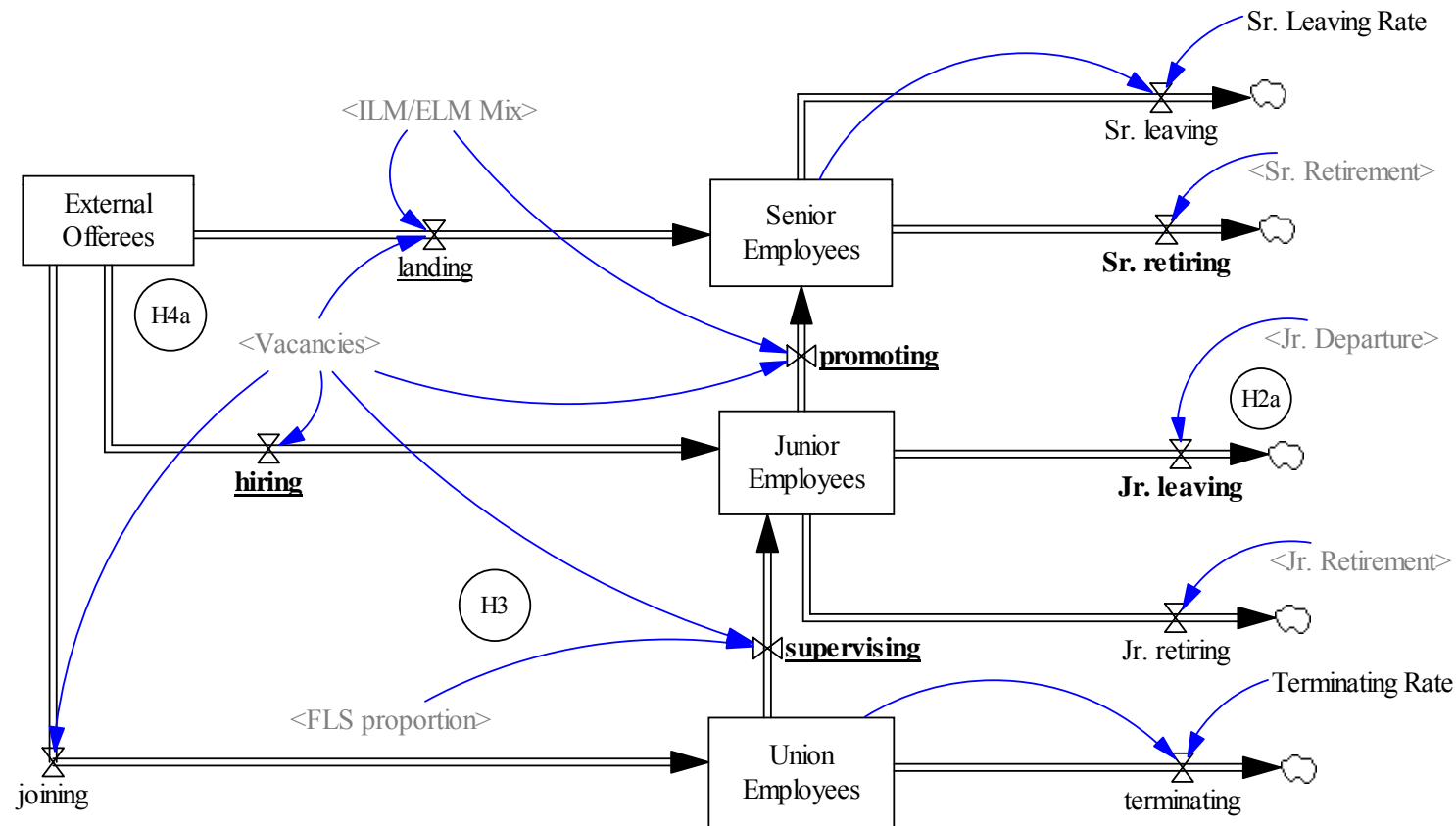


# Individual Level: Personal Departure Criteria Influence Simulation Outcomes



# Firm Level:

## Departure Changes alter Internal Labor Pools



A Brief Case Study:  
Indirect Workforce Effects of  
Total Rewards Reductions

# Case Study: Preliminary Validations

- Model reproduces historical behavior
- Model shows correct behavior at boundaries
- Dimensional consistency is maintained
- Components pass 'Partial Model' tests
- Extreme values yield reasonable results
- Historical behavior is reproduced (Theil inequality stats.)
- Sensitivity analysis is satisfactory (below)

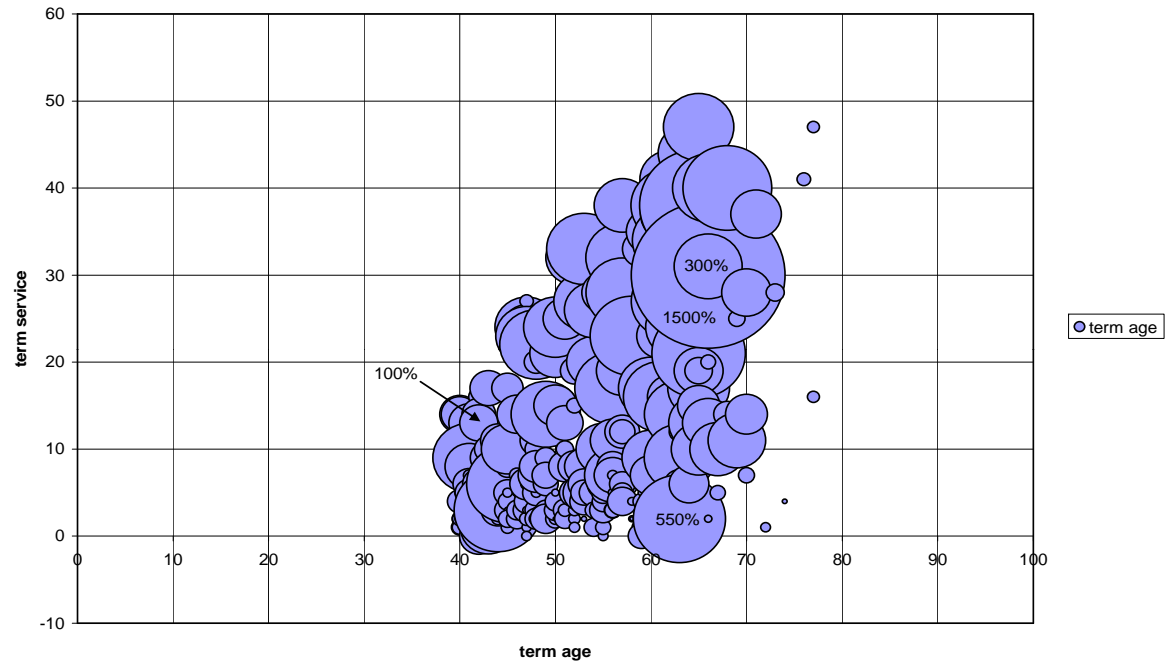
## Case Study: Reproducing Historical Behavior (Theil statistics)

month:	1	13	25	36	48	mean
history	1105	1228	1297	1249	1229	1249
simulated	1111	1256	1280	1226	1214	1236
	$R^2$	$MSE$	$UM$	$US$	$UC$	
nonunion white males	.96	288	<b>.993</b>	.011	-.003	

## Case Study: The Major Unintended Consequences We Considered

1. Individuals decide to retire later.
2. Cumulative retirements delayed (“right shift”).
3. Employee Quits before age 55 increase due to reduced opportunity for advancement
4. Per capita pay and health costs rise.
5. Workforce diversity percentages flatten.

# Issue: Historical Data



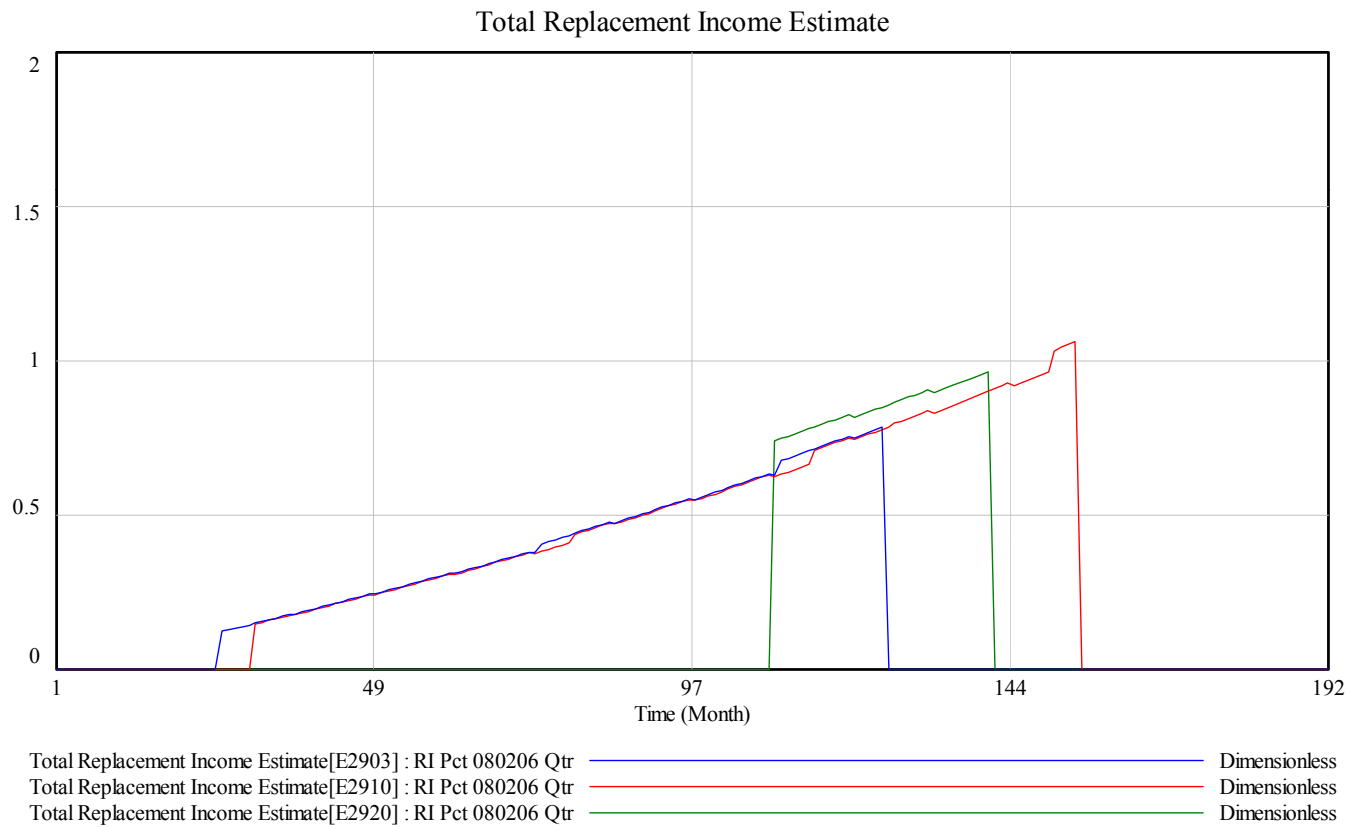
IV	DV	$\eta$	$\eta^2$	
Age	Repl Inc %			$r^2 = .178^{***}$
Repl Inc %	Retire	.065	.004	$r = .048$

# Sensitivity Analysis

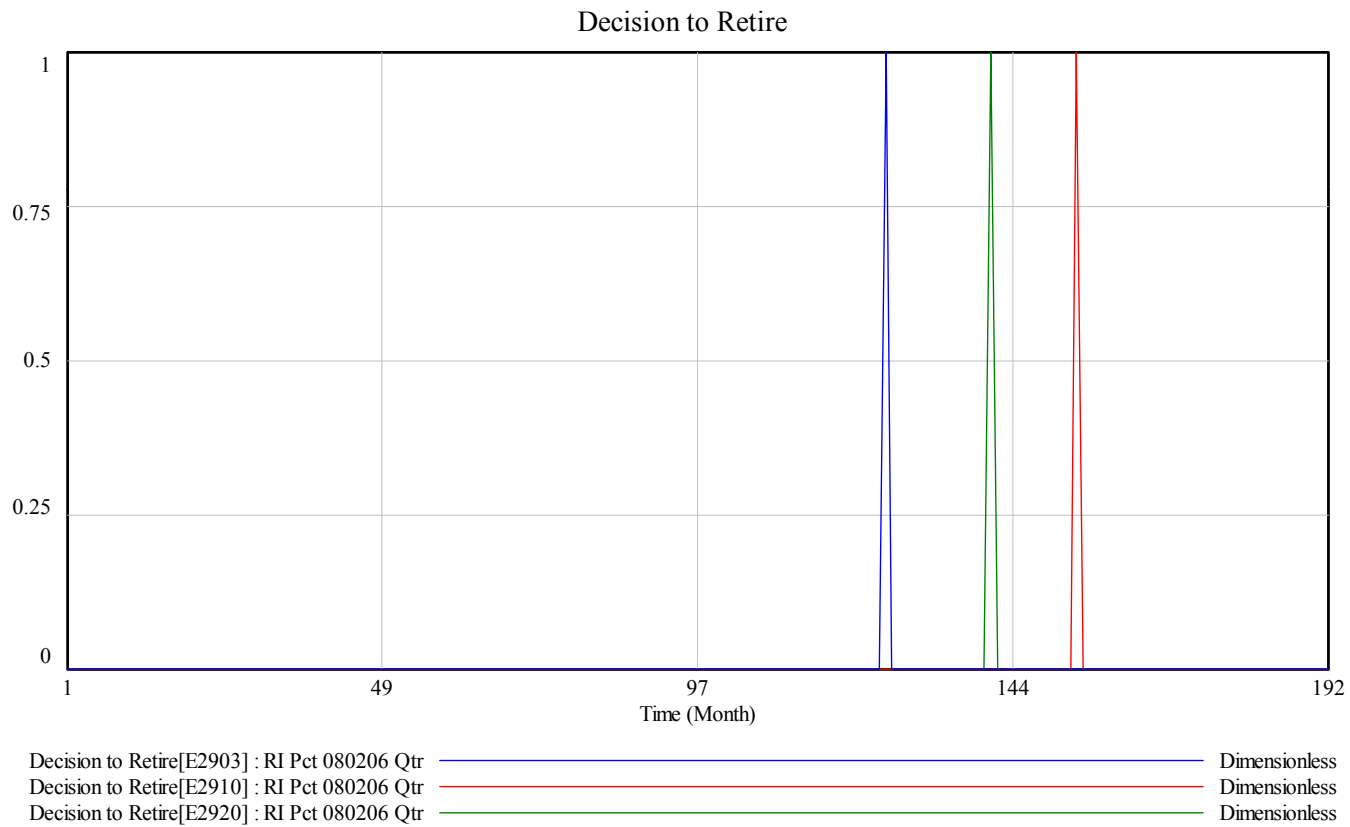
- Added “what ifs?”
- Doubled, quartered monthly values, within Repl. Inc. Pct. cohorts, of retiring.
- Retirements again simulated: if value > random (monthly by employee) numbers.

<b>Experim</b>	Value doubled	Value q'rted
<b>60.1</b> (2.9)	58.9 (2.2)	61.3 (3.2)
<b>685;</b> <b>39.6</b>	575; 38.8	703; 40.1
<b>\$33,127</b>	\$30,742	\$35,829
<b>\$59,453</b>	\$56,675	\$62,759
<b>55%</b>	49%	54%

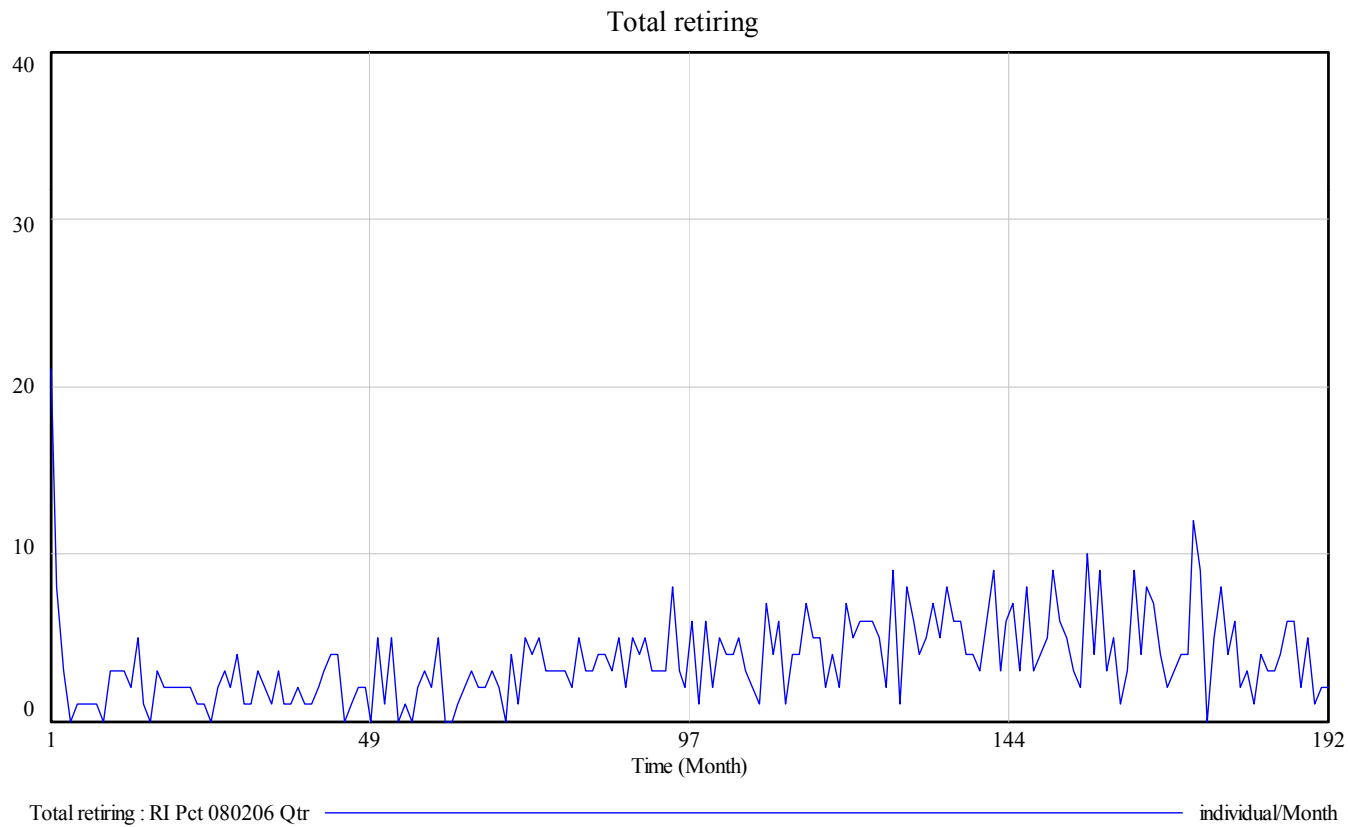
# Why? What's Happening? – 1



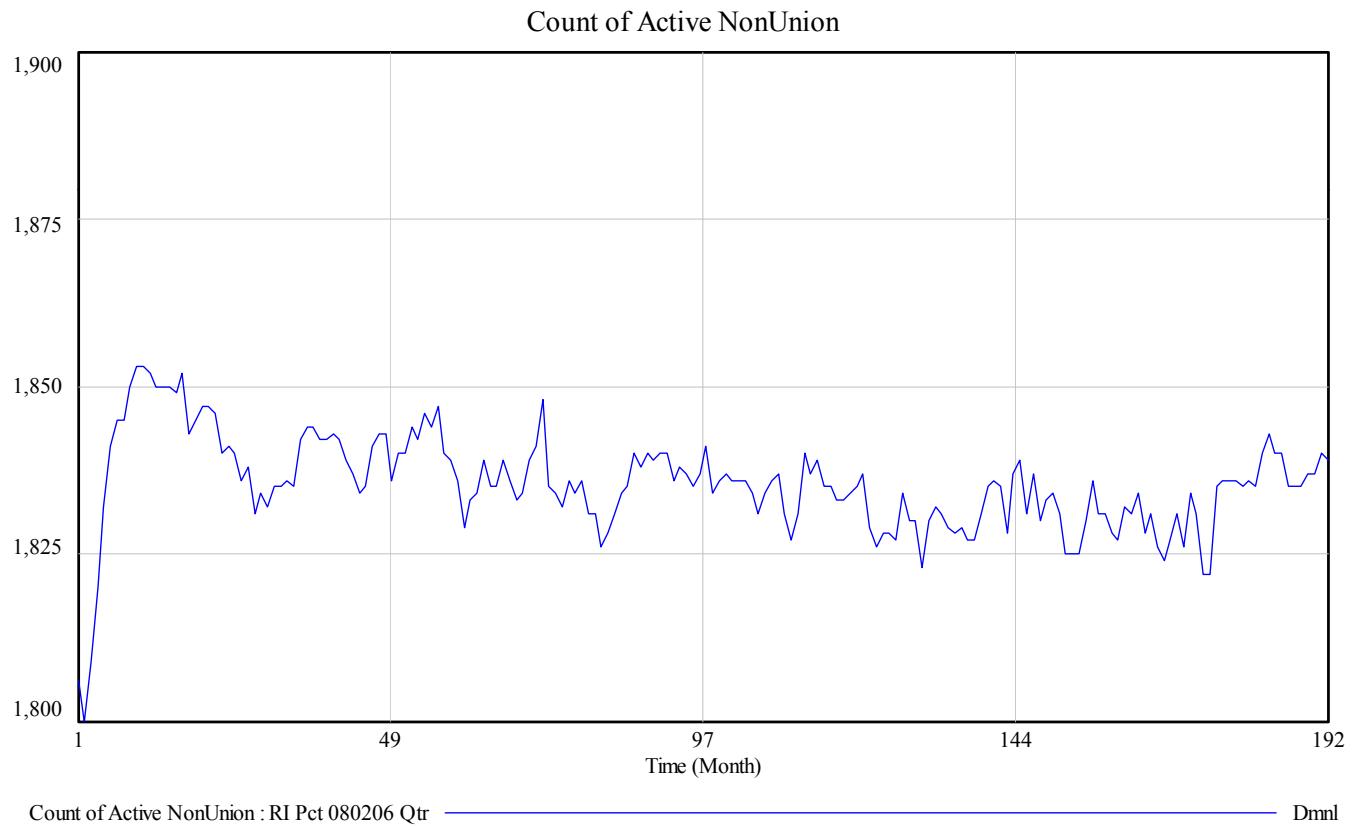
# Why? What's Happening? – 2



# Why? What's Happening? – 3



# Why? What's Happening? – 4



# Summary

# Why Dynamically Model the Firm and its Heterogeneous Employees?

- Approach offers to clients and users desirable integrated insights that are otherwise unavailable.
- Affords a tool to avoid or ameliorate real unintended consequences.
- Provides HR professionals a forecasting method comparable to dominant Finance and Operations tools.
- Method is adaptable to additional questions in strategic HR management.

# Integrated Consulting Insights

This modeling approach fills an HR consulting gap because it:

- exhibits dynamic sensitivity over time,
- spans multiple levels of analysis, and
- explain interactions across levels.

It supports consulting insights into strategic HR questions that span functional silos, intra-organizational boundaries and passage of time.

# Prospective Consulting Overview

- Client Contributes:
  - Available HRIS data, and client's estimates where firm-level data is not available
  - Issues to be explored
- Consultant Contributes:
  - Industry-level data and assumptions as needed
  - Simulation Model, with transparent, malleable structure
- Consultant Delivers:
  - Multi-level HR forecasts with confidence intervals

# Technical Overview

# The Technical Challenges of HR Modeling

- HR Modeling requires policy-feedback modeling, employee-level agency, *and* the flexibility to implement HR-specific sequencing and iteration.
- To build sound HR models it is often necessary to incorporate a fine-grained employee database – an entire embedded HRIS database – in the model.
- Some HR models (e.g., skills-tracking models) may require the tracking and maintenance of thousands of properties for each of many thousands of employees. This creates storage-management and computational challenges at the application level.

## Our Original Solution (2002-2006)

Our original technical solution, adopted during the period 2002-2006, employed *two* proprietary engines designed to work in collaboration:

- **For main model implementation:** A System Dynamics engine using Ventana Inc.'s *Vensim*<sup>®</sup> platform, including a proprietary Agent Based component in the form of an internal employee database
- **For complementary processes:** An SQL-driven proprietary Agent Based data support environment (Microsoft).

## Our Current Solution (2007 -)

Beginning in 2007, to secure better licensing options and better integration among SD, DE, and AB components within our models, we employ:

- **For model implementation:** A set of System Dynamics, Discrete Event, and Agent Based components operating wholly within a single *AnyLogic*<sup>TM</sup> platform (XJ Technologies, Ltd.)
- **For model support:** A database support platform furnishing a data-validation environment and a link among data tables, client HRIS data, *AnyLogic*<sup>TM</sup>, and statistical tools such as *SPSS and Stat::Fit*

# Distribution and Licensing of Models

The following options are now available for the distribution and licensing of our models:

Option	Description	Possible Licensees
<i>AnyLogic</i> <sup>®</sup> Project	A standard, complete, editable AnyLogic project file. The item licensed and distributed would be a standard .alp, used directly in the AnyLogic <sup>®</sup> platform.	Consultants
<i>AnyLogic</i> <sup>®</sup> -compatible library	A standard model or suite of modeling components or utilities, licensed and distributed as a <u>compiled</u> Java file (.jar) for use with the <i>AnyLogic</i> <sup>®</sup> platform.	Consultants Sophisticated End-Users
Stand-alone Software	A complete model, a compiled Java (.jar) program, able to run from the command line or as a Java applet. Runtime software (not the full <i>AnyLogic</i> <sup>®</sup> ) would be required for local use.	Promotional use only. [The distributability of models packaged in this way is excellent, but flexibility is insufficient for real analysis.]

# Planned Enhancements

- Include intra-organizational relationships: incorporate dynamic organizational structures, formal and informal.
- Include dynamic rosters of individual workers' competencies (KSAs) and employers' aggregate competency demands.
- Tie multi-level system model to firm performance: “dock” with Operations models (e.g., Cost, Schedule, Technical).

## Planned Enhancements (2)

- Include multi-national capabilities, including optimization across multiple compensation packages, benefits packages, and regulatory environments
- Implement competitive HR modeling capabilities, including the effects of competitors on hiring.
- Include outsourcing modeling capabilities, including optimization between in-house (agent-based) and outsourced (discrete event) staffing.
- Include labor pool forecasting.

# Additional Information

# Theil Inequality Statistics

- Decompose data series' mean square errors into three components:
  - $U_M$  indicates model bias,
  - $U_S$  unequal variation, and
  - $U_C$  unequal co variation.
- $\sum U = 1$ .
- The results indicate:
  - high replication of historical results by model outputs (viz., all  $R^2$  values exceed 0.83) and
  - almost all variance between the two sets of data series is model bias, a subject for parametric adjustment.

## Theil Statistics – Detail

- Decomposes MSE into three components, bias ( $U^M$ ), unequal variation ( $U^S$ ) and unequal co-variation ( $U^C$ ), which sum to 1.
- $MSE = n^{-1} \sum (x_{\text{model}} - x_{\text{data}})^2$
- $U^M = (\text{mean } x_m^2 - \text{mean } x_d^2) / MSE$
- $U^S = (s_m^2 - s_d^2) / MSE$
- $U^C = 2(1-r)s_ms_d / MSE$

# Sample Repl. Income Pct. Cohorts

RI Cohorts	Annual Prob.	Mo. Prob.	Dbl. Mo.	Qtr. Mo.
0.05	0.04	0.003	0.0068	0.0008
0.35	0.28	0.027	0.0540	0.0068
0.75	0.60	0.074	0.1470	0.0184
1.00	1.00	0.250	0.5000	0.0625
2.00	1.00	0.375	0.7500	0.0938
100.00	1.00	0.750	1.5000	0.1875

# The Right Workforce Model™

