Workforce Evolution & Optimization
Modeling and Optimization for smarter long-term workforce planning

Using Analytics to Optimize Your Workforce
IBM Analytics Solution Center Seminar, Washington D.C.
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IBM Business Analytics & Mathematical Sciences

Over 50 years of significant contributions to the field of mathematical sciences

Over 100 top scientists solving the most challenging problems for IBM and its customers
Workforce Management Initiatives @ Research

For over eight years a team of 25+ researchers worldwide has been involved in the development of workforce analytics, solutions and tooling for internal IBM workforce transformation.

Data modeling, management and mining

Mathematical analytic methods

Learning and collaborative technologies

Software engineering
System development. DB management & integration. Cognos. SPSS.
Motivation

- The services sector forms a predominant part of economic activity in industrialized countries.

- A critical driver of both value and cost in any services operations is its **workforce** (talent, skills, knowledge).

  *The right people, with the right skills,*

  *in the right place, at the right time...*

- Organizations spend hundreds of billions of dollars on IT and programs to manage their people, yet still cite talent as No. 1 issue.

  - existing IT provides fragmented support for single “functions” (e.g. HR, sales, delivery, development, finance)
  - the opportunity to drive business value from IT is shifting from process automation towards people-centric processes (customer service, marketing, innovation, etc)
  - represents and models people as *parts*
Fundamental disruption required: People-Centric Planning

Human capital is more complex to model than parts or inventory in traditional supply chains

- People are not parts
  - Hiring, retaining, acquiring new skills fundamentally influence characteristics of human capital management and planning models and optimization
  - People can be incentivized, can suffer from burnout, under- or over-utilization
  - People learn, evolve and acquire new skills
  - Human talent is not consumed during the service delivery process, representing long-term capital investments
  - Productivity and efficiency depend upon workload and utilization
  - Capable of deploying more than one skill at same time and across multiple service engagements

- Abstractions/Models of people must include
  - Education, geography, teams/networks, skills, performance, preferences, utility functions

New OR models & methods are required to capture and represent these complexities
IBM Workforce Maturity Curve

Following years of investment, IBM has made substantial progress in workforce management transformation, and is one of the leaders in terms of data, process and business understanding.
IBM is investing in the development of novel workforce analytics, and human capital management methodologies as a major competitive differentiator.

**Demand Forecasting**
How many people, projects?
How much revenue/signings?
Which opportunities are likely to be won/lost

**Capacity Planning**
Planning methodologies, optimal demand-to-resource allocation, optimal headcount budget allocation

**Matching & Scheduling**
Optimal allocation of people to projects/opportunities, shift scheduling, people matching

**Salesforce Optimization**
Understanding the true sales capacity, performance / productivity drivers, optimization of sales territories

**Strategic Planning**
Relating workforce decisions to business success. Determining actions and policies to drive optimal workforce composition

**Next-Gen Workforce**
Collaborative tools and technologies. Expertise location and management. Knowledge management. Capturing the social aspects of the workforce

**END-TO-END ENTERPRISE APPLICATIONS**
A Framework for Workforce Analytics

DEMAND FORECASTING
Determining engagement and skill demand
Statistical Forecasting
Machine Learning / Data Mining

RISK-BASED CAPACITY PLANNING
Determining skill capacity targets

WORKFORCE EVOLUTION & OPTIMIZATION
Determining skill supply
Stochastic Temporal Models
Stochastic Optimization/Control

SKILL SHORTAGE & OVERAGE MANAGEMENT
Stochastic Optimization

MULTI-SKILL SHORTAGE & OVERAGE
Matching target against supply
Mathematical Programming
Workforce Evolution & Optimization (WEO)

Unique scenario analysis/modeling tool for studying workforce trends and determining optimal HR policies

“How will my workforce look 3 years from now if we keep our current hiring, training and attrition policies?”

“How to reduce labor cost by 15%-20% in the next year while optimizing the strategic business objectives”

“Does this composition guarantee that my business is running optimally -- if not, which actions we need to take, and which policies need to be changed in order to meet business objectives?”

“Will I have enough of skill A to meet product demand?”

WEO tool empowers strategic workforce decisions with long-term implications to business success

- Analysis of historical workforce trends and dynamics for prior year (e.g., hires, releases, promotions, transfers)
- Predictive modeling of future workforce dynamics based on past activities and sophisticated probability calculations
- Ability to model the future based on ‘what if’ adjustments and scenario modeling
- Ability to optimize strategic decisions relative to business goals (e.g., hiring, releasing, promoting) at any level of views
- Workforce intelligence beyond pie and bar charts, into advanced predictive, analytical and optimization capabilities, delivered in real time through one integrated platform
Long-Term, Strategic Workforce Planning

- Long-term planning considers how the market, technology, organization structure, labor supply, etc. will change in the next few years and how a business should adapt to these changes and turn them into competitive advantages
  - Evolution under current composition/policies and current conditions
  - Determine optimal composition/policies, target states, paths to target states
  - Strategic Analysis/Planning and Scenario Analysis/Planning

- Time scale and time horizon often depend upon industry

- Input from short-term and medium-term planning and feeds outputs back to same
  - Model workforce at a higher, aggregated level rather than at the project level

- Stochastic models are used to analyze, optimize, control dynamic workforce under uncertainty in labor demand & supply, marketplace, and people behaviors/actions
  - Captures complex dynamics of future skill supply by taking into account hiring, training, transfers, as well as changes in organizational policies
  - Discrete-time stochastic process is used to model complex evolutionary dynamics of the skill composition of human talent over planning horizon
  - Optimization of investments and policies to best guide dynamics of future evolution of human talent and skill composition
Talent evolves in complex ways and the planning process requires novel models that capture the stochastic dynamics of hiring, promotions or acquisitions of new skills

- Stochastic workforce evolution models include groups of human capital, internal transitions among HC groups, external transitions from/to marketplace to/from HC groups
  - Consider human capital supply chain with skill groups: C, Java and SQL programmer, and engagement manager

- In addition to complex network topology, stochastic evolution model includes:
  - Probability of internal transitions among human capital groups at time scale of interest
  - Probability of hires/attrition for each human capital group at same time scale
Stochastic Workforce Evolution & Optimization

Our stochastic planning models also need to capture and address the impact of organizational policies and incentives.

- Rewards and Costs can be associated with each human capital group
- Reward and Cost functions can be associated with transitions between groups
- Lead times associated with human capital management and planning actions
Workforce Evolution & Optimization

Most importantly, the planning models should provide a representation that can be controlled to determine the “best possible” workforce composition and the best ways to achieve it

- Determine evolutionary path and future composition of the workforce
- Determine optimal target composition for the workforce over a given horizon
- Determine optimal hiring/training/incentivizing/etc actions to reach this target
First-Order Models

Consider workforce comprised of $N$ resource types over horizon of $T$ periods.

Let $x_i(t)$ denote the expected number of labor resources of type $i$ at time $t$, for all $i = 1, \ldots, N$ and $t = 0, 1, \ldots, T$.

Let $h_i(t)$ denote the expected number of hires of type-$i$ labor resources over the time interval $[t, t+1)$, with expected hiring rate $\lambda_i(t) = h_i(t)/x_i(t)$.

Let $a_i(t)$ denote the expected amount of attrition by type-$i$ labor resources over the time interval $[t, t+1)$, with expected attrition rate $\mu_i(t) = a_i(t)/x_i(t)$.

Let $p_{ii'}(t)$ denote the probability of type-$i$ labor resources that transition to become type-$i'$ labor resources over time interval $[t, t+1)$, $\sum_{i'} p_{ii'}(t) \leq 1$.

When $a_i(t) > 0$, this inequality is strict ($\sum_{i'} p_{ii'}(t) < 1$) and $1 - \sum_{i'} p_{ii'}(t)$ represents the probability of type-$i$ labor resources that leave the workforce.
First-Order Models

Define \( \mathbf{x}(t) \equiv (x_1(t), \ldots, x_N(t)) \) to be workforce state vector for \([t, t + 1)\)

Define \( \mathbf{P}(t) \equiv [p_{i'j}(t)]_{i',j=1,\ldots,N} \) to be the workforce evolution one-step transition probability matrix for the time interval \([t, t + 1)\)

Define \( \mathbf{h}(t) \equiv (h_1(t), \ldots, h_N(t)) \) to be workforce hiring vector for time interval \([t, t + 1)\), with workforce hiring rate vector \( \lambda(t) \equiv (\lambda_1(t), \ldots, \lambda_N(t)) \)

Define \( \mathbf{a}(t) \equiv (a_1(t), \ldots, a_N(t)) \) to be workforce attrition vector for time interval \([t, t + 1)\), with workforce attrition rate vector \( \mu(t) \equiv (\mu_1(t), \ldots, \mu_N(t)) \)

The **dynamics of workforce evolution** over each time step is governed by

- the **number of type-\(i\) labor resources** at **beginning** of time interval \([t, t + 1)\)
- the **inflow of labor resources of type \(i\)** due to **hiring** and **transitions** from other labor resource types over the time interval \([t, t + 1)\)
- the **outflow of labor resources of type \(i\)** due to **attrition** and **transitions** to other labor resource types over the time interval \([t, t + 1)\)
More formally, we have

\[ y_i(t + 1) = y_i(t) + h_i(t) + \sum_{i' \neq i} y_{i'}(t)p_{i'i}(t) - y_i(t)\sum_{i' \neq i} p_{i'i}(t) - y_i(t)(1 - \sum_{i'} p_{i'i}(t)), \]

\[ = h_i(t) + y_i(t)p_{ii}(t) + \sum_{i' \neq i} y_{i'}(t)p_{i'i}(t), \]

\[ = h_i(t) + \sum_{i'} y_{i'}(t)p_{i'i}(t) \]

Or in matrix form

\[ y(t + 1) = h(t) + y(t)P(t) = y(t)[\Lambda(t) + P(t)], \]

where \( \Lambda(t) \equiv \text{diag}(\lambda_1(t), \ldots, \lambda_N(t)) \)
Stochastic Workforce Evolution Models
Supply evolution over the planning horizon

It then follows that

\[ y(1) = h(0) + y(0)P(0); \]
\[ y(2) = h(1) + y(1)P(1) = h(1) + (h(0) + y(0)P(0))P(1), \]
\[ = h(0)P(1) + h(1) + y(0)P(0)P(1); \]
\[ y(3) = h(2) + y(2)P(2) = h(2) + (h(0)P(1) + h(1) + y(0)P(0)P(1))P(2), \]
\[ = h(0)P(1)P(2) + h(1)P(2) + h(2) + y(0)P(0)P(1)P(2); \]
\[ \vdots \]

From which we obtain

\[
y(T) = \sum_{t=0}^{T-1} h(t) \prod_{t'=t+1}^{T-1} P(t') + y(0) \prod_{t=0}^{T-1} P(t) = y(0) \prod_{t=0}^{T-1} [\Lambda(t) + P(t)]
\]
Stochastic Workforce Evolution & Optimization

Determining optimal workforce trajectories and associated organizational incentives and policies subject to business objectives and constraints

Profit-Based Stochastic Workforce Evolution & Optimization:

\[
\begin{align*}
\min & \quad \sum_{t=0}^{T-1} [p(t+1) \cdot y(t+1) - d(t) \cdot u(t)], \\
\text{s.t.} & \quad y(t+1) = y(t) + B(t)u(t) \quad \text{(discrete-time LDS)} \\
& \quad p(t) \equiv (r_1(t) - c_1(t), \ldots, r_N(t) - c_N(t)) \text{ and } d(t) \text{ is action cost vector}
\end{align*}
\]

Stack problem into LP formulation with decision and cost vectors \(z\) and \(w\)

\[
z = \begin{bmatrix}
y(1) \\
\vdots \\
y(T') \\
u(0) \\
\vdots \\
u(T'-1)
\end{bmatrix}, \quad w = \begin{bmatrix}
p(1) \\
\vdots \\
p(T') \\
d(0) \\
\vdots \\
d(T'-1)
\end{bmatrix}
\]
Stochastic Workforce Evolution & Optimization

Determining optimal workforce trajectories and associated organizational incentives and policies subject to business objectives and constraints

In addition to the discrete-time linear dynamical system constraints, we have:

- Constraints on balancing total flow of system resources: \( Q(t)u(t) = 0_{T \times 1} \)

- Constraints on limiting total outflow from each state: \( \tilde{R}z \leq \tilde{y}(0); \ z \geq 0 \)

- Constraints on limiting total attrition for each state: \( \tilde{S}z \geq \begin{bmatrix} L(0)y(0) \\ 0 \\ \vdots \\ 0 \end{bmatrix} \)

- Constraints on revenue as function of demand for each state: \( y^u(t) \leq D(t) \)

where decompose \( y(t) \) into utilized \( y^u(t) \) and surplus \( s(t) \):

\[
p_i(t) = y^u_i(t) \times r_i(t) - y_i(t) \times c_i(t) \\
= y_i(t) \times (r_i(t) - c_i(t)) - s_i(t) \times r_i(t)
\]
Combining these derivations yields the complete specification of our LP:

\[
\begin{aligned}
\min & \quad w \cdot z \\
\text{s.t.} & \quad Mz = \tilde{y}(0); \quad [0 \quad \tilde{Q}] \ z = 0; \\
& \quad z \geq 0; \quad \tilde{R}z \leq \tilde{y}(0); \\
& \quad \tilde{S}z \geq \begin{bmatrix} L(0)y(0) \\ 0 \\ \vdots \\ 0 \end{bmatrix}
\end{aligned}
\]
Numerical Experiment

Demand Forecast (solid) and Optimal Staffing Levels (dashed)

- Type 1
- Type 2
- Type 3
- Type 4
- Type 5

Numbers of Resources

Time periods

1 2 3 4 5 6 7 8 9 10 11 12

S = 3
S = 2
S = 1
S = 7
Numerical Experiments - Evolution
Numerical Experiments - Optimization
OnTheMark (OTM)
Integrated workforce planning solution for services and project-based organizations

- A suite of tools for:
  1. Demand forecasting  “How many projects/opportunities/people/skills”
  2. Capacity planning  “How to optimally satisfy projected demand”
  3. Gap/glut analysis  “How many people to hire in each skill”
  4. Strategic planning  “Are we meeting revenue targets? How much will we close”

- Robust service-oriented architecture that integrates advanced analytics with workforce and business data (Siebel, claims, supply, HR, forecasts)

- Deployed in several IBM units for workforce capacity planning and strategic planning, with significant time and cost savings
Matching highly skilled professionals to open positions is a high-stakes task that requires careful consideration by experienced resource managers. Poor decisions can result in understaffing, under- or over-qualification, and high turnover of poorly matched workers. 

Given DEMAND (a set of jobs described by attributes such as band range, job role, skillset, start and end dates, location, ...), SUPPLY (a set of resources described by band, job role, skillset, location, availability date, ...), and MATCHING RULES - > Find good matches.

OPTIMATCH Benefits: A number of internal IBM deployments. $70M benefits to Global Business Services since 2008, due to more efficient staffing and reduced cost for contracted labor.