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A Taxonomy of Manpower Forecasting and Planning

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Abstract

The literature has recorded many models dealing with manpower forecasting and planning. The approaches used by the various authors are clearly disparate. This paper presents a taxonomy for manpower planning and forecasting methodologies and classifies the landmark developments in this field. The taxonomical schema is then applied to unify the models in consideration of the methods and the decision factors used for forecasting and/or planning. The taxonomy allows for the most complex model structure containing all the factors considered germane in the existing literature.

I. INTRODUCTION

This paper is concerned with a synthesis of landmark developments in the area of manpower forecasting and planning models. The taxonomy developed is based on the methods and the decision factors used in forecasting and/or planning. The most general methodology envisioned by this schema contains all the factors considered germane in the existing literature and it involves the most complex structure. The approach to this work is based on Reisman [1971], Balinsky [1970] and Balinsky and Reisman[1973].

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II. RELATIONSHIP BETWEEN MANPOWER FORECASTING AND PLANNING

Manpower planning can be performed under four principal assumptions regarding the quality of knowledge pertaining to the future. These are: certainty, risk, uncertainty, and ignorance. Irrespective of the quality of knowlege, planning must be preceded by forecasting of the future states or events. The forecasting effort required depends largely on the level of knowledge regarding the states of the future. For example, when certainty about the future is assumed, the forecasting effort required is trivial as there can be but one outcome to a given set of decisions. Under conditions of "risk" the outcomes are assumed to fall into a probability distribution the shape of which and therefore the parameters of which are known. Under the assumption of uncertainty, the outcomes are presumed to depend on scenarios of the future. Therfore, the forecast of outcomes given the future states of events is most valuable to the planning effort as they provide a basis for the justification of any planning decisions to be made. The idea here is that the value of any manpower plan is a function of the quality of the forecast upon which it is based. While this measure of a plan may be true, it is pertinent to add here that the value of knowledge from even the most sophisticated forecasting techniques can not be fully realized unless, of course, the results of such forecasting techniques can be effectively applied in the manpower planning process. Manpower planning has become sufficiently sophisticated that the forecasting and the planning functions have come to be recognized as integral parts, supportive of one another, of the manpower planning process. Two recently published papers in the literature (Fildes 1979 and 1985) provide an excellent review of forecasting methods in general. Some of these methods can, for instance, be used to forecast the parameters needed in a manpower forecast. This paper, however, presents a taxonomy for research in the combined forecasting and planning of manpower area.

The underlying philosophy in developing the classification is :

1. To identify the important factors which have and which might be considered in manpower forecasting and planning models.
2. To show that all existing models can be classified as subcases of the acronym

representing the general model envisioned. The classification for each subcase can be obtained by merely dropping certain terms or writing appropriate subscripts in the general acronym. In this manner it is possible to delineate most, if not all conceivable manpower forecasting and planning models in a systematic fashion.

The classification scheme having been developed is next used to codify the landmark models in the literature. Lastly, it is shown that this approach can also be used to delineate those models which are yet to be developed.

III. DEFINITION OF TERMS USED IN THE TAXONOMY

Let :

H symbolize the length of the planning horizon considered by the methodology: short-range (H_s), medium-range (H_m), and long-range (H_l). Short-range is a horizon of less than one year, medium-range, roughly one to ten years, and long-range, more than ten years into the future.

L symboize the level of planning: national(L_n), regional (L_r), state(L_s), and institutional or company (L_i).

A symbolize the level of aggregation: high (A_h), and low (A_l). A high level of aggregation is characterized by a single category(single profession) and/or high level of geographic lumping e.g. national or regional lumping. A low level of aggregation is concerned with multiple categories(multiple professions) and/or smaller units of geographical, or sectoral lumping.

W symbolize the basic approach used: objective(W_o), subjective (W_s), and mixed (W_m). Objective methods seek patterns or relationships between variables based heavily on historical "hard" data. Subjective methods rely primarily on qualitative or "soft" data, such as judgements/opinions of experts or consumers regarding information or anticipation of future events. Mixed methods combine the objective and subjective methods in such a way that quantitative subjective estimates on parmeter values which are changing due to external factors (e.g, technology, manpower constraints, economy and political realities, etc.) are obtained.

P symbolize the purpose of model: optimization (P_o), policy evaluation (P_e), and forecasting (P_f). Optimization models for manpower planning match the forecasted or projected manpower supply with manpower demand in an optimal fashion. Policy evaluation models measure the impact of alternate assumptions about manpower policies, demand levels, and transition probabilities in the demand process. Forecasting is simply concerned with demand and/or supply forecast.

symbolize the assumed impetus for people movement within the system; push (I_p), pull (I_u), and mixed (I_m). Education of youngsters in a system based on compulsory education is assumed to be a push flow, for example a Markovian [Haggstrom 1971] type model because the students are "pushed" through the system. Recruitment and/or promotion in a work force, on the other hand, are assumed to be pull flows, for example a Renewal [Weber 1971] type model. Manpower planning models sometimes contain mixed flows e.g. part of the pipeline is push type e.g. students in elementary schools and part is "pull" e.g. students graduating from doctoral programs and entering the work force.

These six symbols, HLAWPI with the appropriate subscripts, represent the common factors used in the development of manpower forecasting and planning models and they are used as a basis of classification in this paper. Other factors that are included in some manpower forecasting and planning models but not in all models are described next.

Let :

F symbolize the fact that feedback (closed) loops are incorporated in the model. Closed loops allow outflows to reenter a particular sector of the model. Clearly those models without feedback loops are unidirectional. These latter models allow people to feed forward or thansfer from one sector to another but in one specified direction.

N symbolize that mathematical non-linearities are allowed in the model. Therefore, those models which include any functional representation (or tabular representation), other than those that can be exprssed as linear functions, will be classified as non-linear.

M symbolize the fact that multiple variates are incorporated in the model. Univariate models are based on extrapolation of manpower trends, whereas multivariate models incorporate structural changes and/or environmental circumstances.

C symbolize the cross-sectional structure of the system at a given time. The common feature of all cross-sectional models is that historical data prior to the given time is not required by these models, whereas longitudinal models require a historical time series database.

S symbolize the stochastic nature of the model. If all or some of the flows (recruitment, attrition, promotion, and transfer) are controllable and deterministic, then it is not necessary to have a stochastic model. Voluntary attrition is almost always not controllable and probabilistic but promotion may be controllable and deterministic in accordance with manpower policies.

T symbolize the time-dependent behavior (non-stationarity) of the model. If a system or organiz tion operates over a long period of time with the same expansion rate and recruitment and promotion policies and if the attrition rates do not change, the proportion of people in each grade will reach an equilibrium value. Although in practice one would never expect to reach equilibrium, it is often possible to get quite close to an almost stable system by suitable temporary changes in recruitment (and also possibly early retirement schemes).

IV. THE TAXONOMY SCHEME, HLAWPIFNMCST

The most general model which can be conceived will include all of the above factors. It is symbolized by the acronym $H_hL_lA_aP_pI_i$ FNMCST where the general subscripts take on specific meanings e.g. h can be s, m, or l, etc. This model is conceived to explicitly consider the length of the planning horizon, the level of planning, the level of aggregation, the basic approach applied to the model, the purpose of the model and structural considerations such as feedback loops, non-linearities, multivariates, stochastic nature, and time dependent behavior (non-stationarity). The less complicated models are symoblized simply by deleting the symbols represented by capital letters and/or by specifying the subscripts in HLAWPIFNMCST. For example, a model described as having a long-range planning horizon, directed at a national level of planning, high level of aggregation, using objective methods, optimization, push flows, and having a stochastic nature would be the $H_lL_nA_hW_oP_oI_pS$ subcase of HLAWPIFNMCST. Should it also contain non-stationarity then the model would be the $H_lL_nA_hW_oP_oI_p$ST subcase of HLAWPIFNMCST. Since every model must contain some planning horizon, level of planning, level of aggregation, methodology, purpose of the model, and impetus for people movement every subcase of HLAWPIFNMCST must contain the symbols HLAWPI with the appropriate subscripts. However, if a particular model is applicable to all levels of H, L, or A, respectively, then the subscript is omitted. For example, if a model is applicable to all lengths of the planning horizon (e.g. short, medium, and long), then no subscript appears next to H.

V. CLASSIFICATION OF EXISTING MODELS

Several landmark models recorded in the literature will now be briefly described and classified according to the HLAWPIFNMCST classification scheme

The Bolt, Koltun, Levine Model

Bolt, Koltun, and Levine (1965) derive policy guides relevant to one class of problems, those that involve relations among numbers of academic degrees awarded and the numbers of persons engaged in educating and training the degree recipients. The authors represent the process of degree production by means of a feedback model. Although the analytical method developed is applicable to the production of degrees at any academic level and in any field of learning, It was applied only to degrees at the doctoral level and in the fields of science and engineering. The authors aimed only to develop a tool for helping policy-makers see more clearly the likely consequences of programs and policies contemplated. The model can be classified as the $H_lL_nA_hW_oP_eI_m$F subcase of HLAWPIFNMCST.

Reisman Model

Reisman (1966) offered a conceptual and a mathematical model to study the production of dectorate, master's and baccalaurate degrees and their feedback into higher education. The model breaks the educational sector into four segments : undergraduate, master's doctoral, and post doctoral programs. It breaks the other sectors of society employing college - or university - trained people into segments according to the highest degree earned by those within the segment. Furthermore, it shows the retirement and other attrition sectors more or less as a sink outside of either of the above two sectors. The model delineates the various possible paths for population shifts between the segments. The work is an extension of the Bolt, Koltun, ad Levine model. Its basic advantages are described in the following outline :

1) It recognizes the input of students into the higher education sector.
2) In the educational sector, it distinguishes between persons who haver ecently become engaged in the educational function and persons who have worked in education for many years.
3) It recognizes the non - linearities of the situation studied.
4) It distinguishes between the use of doctorate holders in education at the doctorate, master's and undergraduate levels.
5) It considers the effect of the rates of production of high school, bachelor and master's graduates in successively preceding years.
6) It considers post - doctoral university programs and the interrelated flows from them to teaching at the various levels and to the other sectors employing dectorates.
7) Inasmuch as the rate of doctorate production has changed drastically during the last decades, because of the depression of the 1930's, World War II, and other wars both hot and cold, it emphasizes that the age mix is not a uniform one, Thus, the nubmer of degrees granted some years prior (30 or 35 years) is the independent variable used in calculating attrition in the model.
8) Concern for economic, social, and physical influences in doctorate production and shifts in employment may be built into it. With these advantages accounted for, the Reisman model could be classified as the $H_1L_nA_bW_nP_nI_nF$ N M subcase of HLAWPIFNMCST.

<u>Reisman, Dean, et al Model</u>

Reisman et al [1973] discussed the methods and the results of a ten year forecast for the demand for operative and obstetrical procedures and the supply of anesthesiologists in Cuyahoga County, Ohio. Several regression models were used to forecast supply based on population, number of physicans, and the income per capita. The demand models were based on population, age and sex distribution projections, and historical data regarding operative and obstetrical procedures.

The results of these "objective" models were then compared to forecasts under uncertainty generated by a panel of experts using the Delphi Method. Alternative states of health care delivery were investigated and implications for future anesthesiologist manpower requirements detailed. The model could be classified as the $H_t L_r A_k W_m P_f I_p$NMS subcase of HLAWPIFNMCST.

<u>Charnes, Cooper, Niehaus Model</u>

Charnes et al [1971] developed the first analytical model which explicitly provides for training as well as outside recruitment and job transition possibilities by providing access to a variety of techniques such as "parametric variation" and "duality evaluation" in order to facilitate experimentation with manpower program possibities. In this way it brings the power of linear programming to bear in evaluating optimal trade - off possibilities and the resulting manpower mix and planning consequences. It then coordinates "career planning" and "manpower mixes" and trade-off possibilities in recruitment, transfer and training. Naturally, it accomplishes this in a context that also considers other constraints such as financial budgets, supply and recruitment limitations imposed by policy or the environment at various times and also considers, of course, various kinds of limitations on training facilities. This model involves embedded Markov processes and hence is probabilistic in character. The Charnes, Cooper, Niehaus model could be classified as the $HL_i A_1 W_v P_r I_p$MS subcase of HLAWPIFNMCST.

<u>Hayne and Marshall Model</u>

Hayne and Marshall [1977] presented an extension of the Markov model to one with a two - dimensional state space. The state space is chosen so that the fractional flow matrix has a special structure which is then exploited. The probabilistic properties are discussed in detail with emphasis on computation. The basic equations of manpower stocks and flows are analyzed. The model could be classified as the $H_t L_n A_1 W_v P_r I_p$MS subcase of HLAWPIFNMCST.

<u>Grinold and Stanford Model</u>

Grinold and Stanford [1974] considered a fractional flow model of a graded manpower system and developed algorithms for calculating optimal control policies in four situations :

1. finite time horizons with no constraints on staff distributions
2. finite time horizon with constraints of final staff distrbutions
3. infinite horizon with constraints on staff distributions
4. problms with a nonstationary transient stage and an infinite stationary stage.

In each case, results developed in solving the simpler problems are useful in analyzing the more complicated situations. In addition to providing computational procedures the authors apply the algorithms to a three rank model and discuss the possible uses and limitations of their procedure. This model could be classified as the $HL_iA_nW_aP_aI_nMN$ subcase of HLAWPIFNMCST.

Kwak, Garrett, Barone Model

Kwak, Garrett, and Barone (1977) presented a stochastic technique for short-term demand forecasting of manpower requirements for a particular functional skill group. The demand model is adaptable to any organization in which the demand for services from a skill group is derived from several projects of activities. Working from these multi-project demands for skill group services, Bayesian decision analysis is used to produce a composite forecast of total skill group manpower demand . Options in the model provide for selectively varying the number and level of detail of the mulit-project demand curves. The output of the model is useful for further manpower planning. The model may be cassified as the $H_sLA_nW_aP_fI_pMS$ subcase of HLAWPIFNMCST.

Kahalas and Gray Model

Kahalas and Gray (1976) examined an approach that can be used by firms to solve one of the most pressing of today's employment problems. In effect, the problem becomes one of determining an optimal work force composition based on both sociological and skill components. The problem is viewed as one of establishing rank ordered priorities among multiple conflicting manpower objectives. The authors discussed some of the internal and external constraints faced by the firm and suggests a particular technique, goal programming, to facilitate the manpower decision making process. The technique is examined under two different circumstances to provide some indication of the model's flexibility. The model might be classified as the $HL_iA_tW_aP_aI_mM$ subcase of HLAWPIFNMCST.

Clowes Model

Clowes [1972] developed a two-stage dynamic model to represent the process of labor turnover. The model provides a good fit to a wide range of published turnover data. The author defined labor turnover in terms of primary and secondary termination processes separated by an induction period. The rates of the two termination processes vary markedly between firms: firms with low initial labor turnover rates do not necessarily have low secondary labor turnover rates and vice versa. The rates at which recruits adapt to the ways of different firms are markedly similar. The parameters controlling the turnover process seem to have a realistic significance in terms of quantifying some of the factors involved in the interaction of personnel and organizations. If the model is valid, then its use in the analysis of labor turnover data would make it relatively easy for a particular firm to pinpoint those factors which result in its particular type and level of labor trunover. The model could be classified as the HL.A.W.P.I.NMS subcase of HLAWPIFNMCST.

Grinold Model

Grinold [1976] examined a longitudinal model of a manpower system. The demand for effective manpower is determined by the state of a finite Markov chain. There are delays in the training process. Thus it is not always available to meet demand. He presents an operational method for calculating optimal accession policies. This calculation can in turn be used to find the equilibrium operating rules for the system. The model is a useful device for measuring the impact of alternate assumptions about continuation rates, manpower utilization policies, demand levels, and transition probabilities in the demand process. The model could be classified as the HLAW.P.MS subcase of HLAWPIFNMCST.

Weber Model

Weber [1971] presented a complex system model as a tool for corporate manpower planning. The approach permits representation of the interrelationships between the behavior of individuals as entities, personnel policy decisions, the labor market, and a large number of individual and organizational outcomes. A computer simulation of the model in the context of a managerial and professional hierarchy is described and tested against hypotheses from the managerial and behavioral science literature. The implications of the results of these tests for the usefulness of this approach for manpower planning and other purposes are discussed. The model could be classified as the HL,A,2;W,P,I,MST subcase of HLAWPIFNMCST.

Reisman and Taft Model

Reisman and Taft (1972) attempted to develop a conceptual and a mathematical model to study the production of Doctorates, Master's ans Baccalaureate degrees and their feedback into higher education. The model consisting of over 200 non-linear difference equations. It was programmed for computer simulation and validation against historical data. Current simulation was used to describe what has happened in the past. Once this phase was accomplished, the model was intended to project what might happen in the future. This model could be classified as the H,L,A,W,P,I,FNMST subcase of HLAWPIFNMCST.

Young and Vassiliou Model

Young and vassiliou (1974) presented a stochastic model of promotion in an organization whose vacancies in higher grades to be filled by promotion fluctuate from year to year as organizations develop. Thus the probabilities of individuals being promoted are not static. The model is based on an ecological principle that the probability of promotion depends on the number available to be promoted and on the vacancies to be filled. The promotion patterns are modified by the application of a principle of inertia which takes into account the tendency of staff to expect consistent promotion prospects. Results of testing the model in a large firm subjected to reorganization are given. The model could be classified as the H,L,A,W,P,I,NMS subcase of HLAWPIFNMCST.

Milkovich, Annoni, and Mahoney Model

Milkovich et al (1972) considered a case study in the development, implementation and evaluation of the Delphi technique, which systematically makes use of expert judgment in generating manpower forecasts. The study was conducted in a large national retail organization and concerned professional manpower. The results of the Delphi technique were compared with results generated by conventional regression based models and the actual experience of the organization. The study also analyzed the informational elements used by experts during the Delphi processes and developed a model based on these elements. The usefulness of the Delphi in generating manpower forecasting models was also discussed. The model could be classified as the HL,A,W,P,I,MS subase of

HLAWPIFNMCST.

Haggstrom Model

Haggstrom [1971] developed three projections (model A, B and C) based on different market and economic conditions and the impact these have had on graduate school entry and graduation rates. Projections of model A were considered to be optimistic, model B's were expected and model C's were conservative. Haggstrom used a recursive model which relates current year's graduate enrollment to prior year's enrollment plus new entrants. Three equations represented the enrollment of students in the first year, intermediate and final year levels of doctoral education. To predict the graduate enrollments and degree production of the 1970's, Haggstrom considered the effects of various external events, such as military draft, federal funding for research and education, federal GI bills, etc. This model could be classified as the $HL_aA_lW_aP_fI_p$ subcase of HLAWPIFNMCST.

Dean, Reisman, and Rattner Model

Dean et at [1971] analyzed the supply and the demand for doctorates, using a feedback flow model which depicted the supply of doctorates as a funcction of university faculties ability to produce graduates and the extent of their subsequent re-entry into the university environment. The total demand was estimated via regression and Delphi analysis using GNP and corporate profitability estimates as the independent variables. The model may be classified as the $H_lL_aA_hW_mP_fI_pF$ subcase of HLAWPIFNMCST.

VI. CONCLUSION

This paper developed a taxonomy, intended to classify manpower forecasting and planning models. Landmark models which appeared in the literature were summarized as indicated in Fiqure 1 and classified using the scheme developed. The classification scheme shows, in an efficient manner, the similarities and the differences of all models considered. This scheme can also be used to pinpoint areas for future research as shown in Reisman [1987].

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FIGURE 1

Authors	Length of Planning Horizon H	Level of Planning L	Level of Aggregation A	Basic Approach W	Purpose of Model P
1. Bolt, Klotun & Levine (4)	long range	national	high	objective	Policy Evaluation
2. Reisman (20)	long range	national	high	objective	Policy Evaluation
3. Reisman, Dean et al (21)	long range	regional	high	mixed (objective & subjective)	Forecasting
4. Charnes, Cooper and Niehaus (6)	medium	institution/ company	low	objective	Evaluation
5. Hayne and Marshall (15)	long range	national	low	objective	Evaluation
6. Grinold and Stanford (13)	medium	institution/ company	high	objective	optimization
7. Kwak, Garrett and Barone (17)	short	institution/ company	high	objective	Forecasting
8. Kahalas and Gray (16)	medium	institution/ company	low	objective	Optomization
9. Clowes (7)	medium		low	objective	Evaluation
10. Grinold (7)				objective	Optimization
11. Weber (23)		institution/ company	low	objective	Optimization
12. Reisman and Taft (22)	long range	national	high	mixed (objective & subjective)	Forecasting
13. Young and Vassiliou (24)	long range	institution/ company	low	objective	Evaluation
14. Milkovich, Annoni and Mahoney (18)		national	high	mixed (objective & subjective)	Forecasting
15. Haggstrom (14)		national	low	objective	Forecasting
16. Dean, Reisman, and Rattner (8)	long range	national	high	mixed (objective & subjective)	Forecasting

People Movement I	Feedback F	Non-Linear N	Multi-Variate M	Cross-Section C	Stochastic S	Non-Stationarity T
mixed	x					
mixed	x	x				
push		x	x			
push			x		x	
push			x		x	
push			x		x	
push			x			
mixed			x		x	
mixed			x			
push			x		x	
mixed			x		x	x
mixed			x		x	x
pull			x		x	
mixed			x		x	
mixed			x		x	
push						