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# The Potential Use of System Dynamics in Human Resources Modeling

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## Abstract

Human resources management is one of the basic inputs in order to get the desired level of armed forces and make these forces ready when needed. Because of this reason, all of the Armed Forces (AF) should have personnel systems to perform the mission with the sufficient quantity and suitable personnel. The recent developments in Human Resources Management (HRM) raise the importance of objective planning systems with respect to the subjective ones. There are various existing studies about the human resources modeling. Most of them are large-scale modeling tools, which require skilled personnel and considerable time to set up before they can be run to get results. But if we are dealing with strategic human resources planning issues, the potential of a smaller-scale modeling tool based on generic system dynamics software might fit into our purpose as a rapid prototyping capability in terms of required personnel and time. The aim of this paper is to explain how a system dynamics capability fits into the strategic human resources modeling picture as a complement to the large-scale modeling tools.

**Keywords:** modeling and simulation, system dynamics, human resources modeling.

## 1. Introduction

The modern strategic human resources management approaches; put the importance of human resources for building a sustainable competitive advantage; focus on merging the organizational purpose/strategy and other factors together and; aim to improve the organizational performance through the effective HRM models and tools [1].

Most of the existing applications about the human resources modeling, like Enterprise Resource Planning (ERP) software, are large-scale modeling tools, which require skilled personnel and considerable time to set up before they can be run to get results. But if we are dealing with strategic human resources planning issues, the potential of a smaller-scale modeling tool based on generic system dynamics software might fit into our purpose as a rapid prototyping capability in terms of required personnel and time.

Planning of human resources using classical methodologies such as mathematical models having probabilistic techniques gives rather static results. But modern human resources planning systems require dynamic structural analysis models supported with delayed feedback mechanisms [2].

System dynamics was developed by Jay Forrester in 1961 at the Massachusetts Institute of Technology when he developed the system dynamics programming language DYNAMO. Unfortunately, DYNAMO was not very user-friendly and system dynamics was relegated primarily to educational institutions. With the implementation of user-friendly modelling environments for building system dynamics models on desktop computers, system dynamics has resurfaced among business and public sector strategic analysts.

System dynamics can be thought of as a computer implementation of a fluid flow simulation. Models consist of reservoirs (also called stocks) and fluid flows (or simply flows). The flows into and out of reservoirs are controlled by valves that can be opened or shut based the wishes of policy makers. Information about trends in the stocks and flows can be tracked by policy makers and decisions made about the opening and shutting of the valves based on this information.

There is a parallel between fluid flow modelling and personnel flow in large organizations like Armed Forces (AF). The reservoirs are the personnel in trades, in ranks or in the AF as a whole. The flows are

between ranks, with the training system and with the outside world. AF personnel managers can make policies affecting flows into and out of the reservoirs based on the information that is available on the reservoirs and the flows, and this in turn affects the contents of the reservoirs. Notice, however, that the level of resolution in this type of model is quite low and should only be used for gaining a strategic overview of the situation.

So, it worth to investigate the potential of system dynamics modeling in strategic human resources planning. To test such potential, a typical promotion system within AF was modeled using a SD modeling environment since it allows to build quick prototype models. Through the use of model, the promotion system was monitored to see whether the projected and actual personnel levels were met or not over time according to the expected attrition rates at each rank. In the long run, it was observed that projected levels were met by the actual levels. Using such model, it is also possible to test effects of several policies concerning the size of input over time to meet the future personnel levels.

## 2. Human Resources Modeling and System Dynamics

A classic model in the world of system dynamics is called an "aging chain". In an aging chain, raw materials pass through a system of connected stocks receiving processing at each stage until they become finished products. From the point of view of human resources modeling, this could be used to model the recruiting and training system. Examples are the "Street to Fleet" system [3], the promotion system as commissioned or non-commissioned members move up the rank structure [4] or the trade structure in which members are recruited, trained and promoted within a particular occupational classification. Earlier approaches to aging chain problems have some drawbacks such as insufficient modeling of dynamic complexities, feedbacks, delays and interactions between state variables. But System dynamics has holistic approaches to real-world systems under investigation with its suitable modeling mechanisms compensating the drawbacks of previous approaches [5].

The three salient features of system dynamics are the ability to model feedback, delays and transient behavior. These modelling features are useful in understanding the dynamics of complex systems. Feedback can cause second order effects that are otherwise unpredictable. Delays can separate cause from effect, which also make prediction of the outcome of policy changes difficult. These features are ideally suited to HRM issues in the AF. A change in recruiting, release or promotion policies can have very long-lasting effects that may not be realized at the time it is implemented. These effects can be observed in the form of feedback and in the form of delays that occur in the implementation of the change. Furthermore, the personnel system is always in a state of flux. It is constantly being affected by the external and internal environment, which means that personnel flow never reaches steady states. Therefore, modelling the transient behavior of the stocks and flows can be a very useful tool in personnel studies.

### 2.1. An Example: Officer Flow Model

Figure 1 outlines the structure of the basic career flow features for AF Officers. The lowest rank is Captain/ Lieutenant followed by Major, Lt. Colonel and Colonel. Most officer occupations permit a linear progression of ranks from Capt/Lt to Col. The numbers of personnel at each rank at any one time are the stocks maintained and shown in the rectangular boxes. Initial values for these stocks are shown on the left side. The AF mandates the numbers of individuals to serve at each rank annually through the number of positions for trained officers, known as the preferred manning level (PML) and the number of trained officers, known as trained effective strength (TES). These are shown to the right of the rank boxes. The PML difference, or the deviation of the current stock from PML, is calculated. Attritions are the losses from the system over the years for several reasons (health, casualties, retirement etc.) Officers through this hierarchy are subject to a certain, and in this model, fixed rate of voluntary attrition. This causes an annual outflow of personnel from the system. These are shown to the left of the rank boxes.

The requirement to meet PML induces promotion flow, drawing officers in lower ranked positions to higher ranks. These are shown by the double-lined vertically directed arrows between boxes. As promotions are made, the stock of personnel in the source rank is reduced, increasing the annual outflow

from the source rank. The result of promotions throughout the system is that all vacancies ultimately percolate towards the Capt/Lt rank. Any shortage at this rank should be made up by qualified intake.

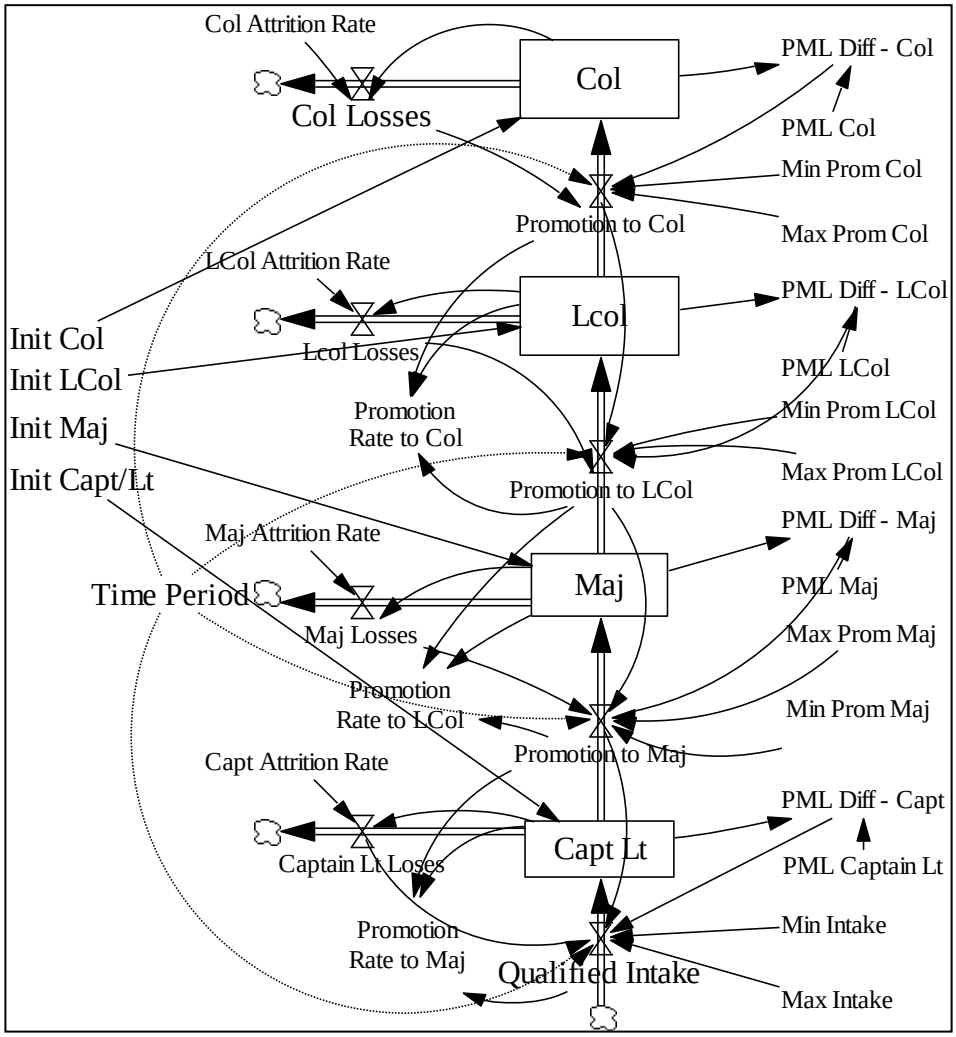


Figure 1: Simplified Career Flow of AF Officers.

In this model, promotion at each rank as well as qualified intake can be constrained by a flow maximum and a minimum. A maximum might be imposed if the capacity to generate adequately qualified officers is limited. Typical flow minima are zero although non-zero quantities may be required to ensure succession planning. Under steady conditions, with attrition rates and PML constant, and with adequate intake capacities, this flow system with its feedback mechanism can rapidly develop a level of intake ensuring that PML is met.

This model brings forward important measures of system performance, such as population levels and anticipated intake, losses and promotions. As is, the model can give good order-of-magnitude estimates for these key measures. The model gives no information about age or years of service of the underlying population.

The reality of officer career development is more complex. Attrition rates strongly depend on some surrogate of years of military experience, and may vary due to economic and social factors. Promotions are often constrained to occur within preferred time-in-rank ranges. Structural policies such as the contract extension point at 20 Years of Service and the mandatory retirement point at some age have to be considered. Amplifying this model to include these features is possible but the resulting structures are far more difficult to manage and data collection for presentation becomes more complex.

A sample application of the model shown in Figure 1 follows. Initial values for PML and TES were obtained from the Spring 2000 Projected Status Report (PSR) of Canadian Forces [6]. Attrition rates were derived from the release and re-engagement values found in the PSR. These are shown in Table 1.

Table 1: Attrition Rates by Ranks.

| | **PML** | **TES** | **Attrition Rate** |
|---|---|---|---|
| **Col** | 232 | 272 | 8.5% |
| **LCol** | 924 | 926 | 6.0% |
| **Maj** | 3068 | 2921 | 5.3% |
| **Capt/Lt** | 6720 | 6381 | 4.9% |

Qualified intake was limited to a range of 300 to 700 officers a year. This model was run for 10 years. The most significant impact of these assumptions is shown in Figure 2.

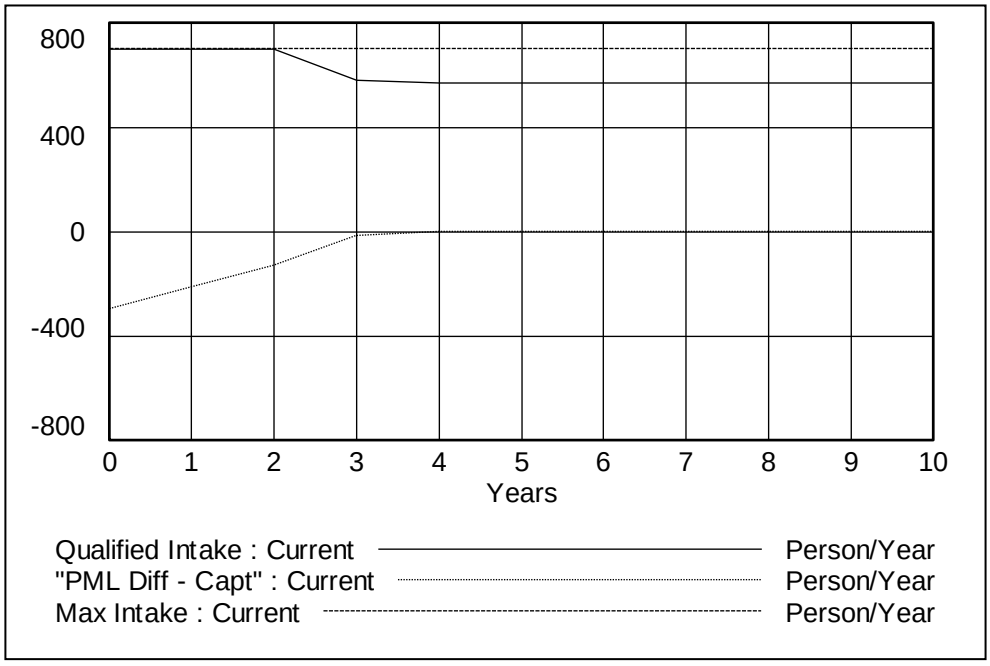


Figure 2: Qualified Intake Response to PML Difference.

The Figure **2** shows how qualified intake has to respond to the PML shortage existing for Capt/Lt. For the first three years, the intake requirement exhausts the assumed maximum capacity of qualified intake. After the third year, when the PML target is expected to be reached, production should run at approximately 570 officers a year for the foreseeable future.

Clearly, a sensitivity analysis can and should be performed. For example, the long-term attrition rates presented in Table 1 can be made to vary with time. This may be achieved by specifying a relationship between attrition and external factors, or by varying attrition randomly within specified limits. PMLs and intake limits might also be subject to change. System dynamics permits the rapid assessment of each of these options, defining areas of stable behaviors in the parameter space.

### 2.2. Other Example Uses of System Dynamics in HRM

The personnel policies relating to recruitment, training and retirement could be effectively modelled using system dynamics, as could promotion policies to senior rank levels. Cost analyses and trade-off studies could be facilitated in a timely, though only in an aggregated, manner [7]. In another study,

ability, motivation, and opportunity (AMO) factors affecting English Teachers' performance were investigated using system dynamics [8].

Using system dynamics, sensitivity studies to find high impact leverage points can be performed far more rapidly than by using the higher resolution methods. This ability can be very useful to senior leaders as they develop information-gathering tools to support their management controls.

In some simple cases, spreadsheet (e.g. MS Excel) and database (e.g. MS Access) applications can also be used in rapid-prototyping and analysis. But it is not possible to include feedback that causes dynamic behavior with these tools. Since numerical integration methods are poor in spreadsheets, 'time' cannot be easily represented.

Most of the AFs have enterprise models at departmental level. Such a model describes the management processes and data flow supporting strategic level decision-making. To utilize such an enterprise model as a learning tool for senior officers, it would be helpful to create numerical simulations. A possible approach would be to build a personnel management simulator based on the processes defined in the enterprise model using the prototyping and assessment technology of system dynamics.

### 2.3. Discussion

Having discussed the possible uses of system dynamics in human resources modeling, it's better to define a framework for such usage. There are strategic and operational level issues in human resources that differ both in the *scope* that is required to adequately develop models and decision support tools, and in the level of *resolution* that is required in the input and output for these models. In general, the more strategic the study, the larger the scope, the lower the resolution required and, in general, the higher the level it is.

Table 2 presents a list of current human resources related modelling and analysis activities in AF human resources planning.

Table 2: Classification of HR Related Modelling and Analysis Activities in HR.

| NO. | TITLE | LEVEL |
|---|---|---|
| 1. | Monitor, Analyse and Assess HR Implications of Socio-Demographic, Organisational and Technological Trends in the Population and in the AF | High |
| 2. | AF Recruitment Attrition Model | High |
| 3. | Provision of Analytical Support for Strategic HR Policy Development | High /Mid /Low |
| 4. | AF HR Service Requirements Modernisation | Mid |
| 5. | Officer and NCM Occupational Demographic Profiles | Mid |
| 6. | Human Resource Cost Models | Mid |
| 7. | Modelling of Sub-Populations | Mid |
| 8. | Cost of Moves for AF Personnel | Mid |
| 9. | Annual Military Occupational Reviews | Low |
| 10. | Occupational Structure Implementation Plan Support | Low |

A What-If type tool for the first purpose would be very large in scope and therefore very well suited for global studies. A tool for the third purpose would also have very high resolution and ideally suited for detailed policy analyses. A system dynamics modeling software should assist in making the transition between these two and transferring results from the operational level (mid to low) to the strategic level (high) and back again.

Although system dynamics is best used for low-resolution studies, it can be used in a rapid-prototyping mode to support short studies that are common in AF policy making, where low-resolution is acceptable

and fast turnaround is required. In contrast, high-resolution models are believed to be quite time-consuming to set-up, run and produce results.

## 3. Concluding Remarks

Personnel human resource modeling in AF can be supported by detailed and global level applications. But these tools involve extensive databases and can produce results at very high resolution. However, they can take some time to setup and produce results. System dynamics software, on the other hand can fit into this suite of tools at the operational level when rapid-prototyping is required and high resolution in the input and output is not required.

The system dynamics modelling principles of feedback, delays and transient behavior can be applied rapidly to personnel policy issues in large organizations like AF. Through successful application of system dynamics, an awareness of availability and potential of this mid-level policy analysis tool should be created among senior leadership.

In this work, only the promotions of officers for only single branch were modeled. There are more than 20 branches for officers and around 100 branches for non-commissioned officers in each service. If we consider all services (Army, Navy, Air Force, Gendarmerie and Coast Guards) we have to model nearly 500 categories and hundreds of career patterns between them. So, this indicates how complex the system is and how system dynamics is capable of modeling such complexity.

As a future research, a more detailed promotion model development is planned. The data requirements for such model can be met with some simple data such as overall number of personnel at each rank initially. As obtained, more detailed data can be fed into the model such as attrition rates obtained by investigating the past data, PML data from the future force structure. Several promotion policies and their effects in the long term can be analyzed using such model.

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