A Civilian Prototype Occupational Projection Model Using Arena

Purchasing and Supply Group Modelling - Lessons Learned

Stan Isbrandt
Workforce Modelling and Analysis
Personnel Generation Research

Fariya Syed
Director Science and Technology Personnel

DGMPRA TM 2010-015
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Defence R&D Canada
Director General Military Personnel Research and Analysis

Chief Military Personnel

National Defence Défense nationale

Canada

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Principal Author

(Original signed by)

Stan Isbrandt, MMath

Approved by

(Original signed by)

Douglas Pelchat, BA
Section Head – Personnel Generation Research

Approved for release by

(Original signed by)

Kelly Farley, PhD
Chief Scientist – Director General Military Personnel Research and Analysis

The opinions expressed in this paper are those of the authors and should not be interpreted as the official position of the Canadian Forces, nor of the Department of National Defence.

Abstract

Within the Canadian Department of National Defence, a prototype civilian workforce simulation model was developed for the modelling and analysis of one particular occupational group, the Purchasing and Supply (PG) Group. The model was developed to explore workforce modelling techniques for the civilian workforce with the intention of potentially modifying it for analyses of other occupational groups, and eventually producing a generic civilian occupational group modelling capability. This paper outlines the methodology, the determination of occupational characteristics for modelling purposes, preliminary occupational analysis, lessons learned, and a possible way forward for the workforce modelling of civilian groups.

Résumé

Un prototype de modèle de simulation de la main–d'oeuvre civile a été mis au point au sein du ministère de la Défense nationale du Canada afin de modéliser et de faire l'analyse d'un groupe professionnel particulier, le groupe Achats et approvisionnements (PG). Le modèle a été élaboré afin d'explorer les techniques de modélisation de la main–doeuvre de l'effectif civil, dans le but de le modifier un jour afin de pouvoir analyser les autres groupes professionnels et d'éventuellement produire une capacité générique de modélisation des groupes professionnels civils.

Le présent document décrit la méthodologie, le mode de détermination des caractéristiques du groupe professionnel pour les besoins de la modélisation, l'analyse préliminaire du groupe, les leçons retenues et les éventuelles prochaines étapes de la modélisation de la main–d'oeuvre des groupes civils.

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Executive summary

A Civilian Prototype Occupational Projection Model Using Arena

Stan Isbrandt, Fariya Syed; DGMPRA TM 2010-015; Director General Military Personnel Research & Analysis; August 2010.

Although the Department of National Defence (DND) has an extensive history of military occupational modelling, the simulation and modelling of civilian occupations has not been developed to the same level. This paper describes a beginning prototype model, based on projections for one particular occupational group within DND, namely the Purchasing and Supply (PG) group.

Within Assistant Deputy Minister (Materiel) (ADM(Mat)) the Community Management Office (CMO) wanted to have modelling projections made for the PG group. This was seen to provide an opportunity to develop a prototype model to handle a real situation of interest, and to help show the way for an eventual more robust civilian occupational modelling tool. Descriptions are provided of how the model simulates flows of individuals within the PG level structure over time to provide future projections. Two scenarios are analyzed, a "Status Quo" scenario where the establishment numbers for the PG levels are held constant, and a "Growth" scenario where the establishment numbers for the PG levels increase incrementally over the first five years. Some illustrative sample results which illustrate projections over a 20-year period are presented.

Some "Lessons Learned" from the development of the prototype model, as well as from previous military occupational modelling analyses, are provided. Also, some suggested "Next Steps" are given for how effort might continue towards building a more generic civilian occupational modelling tool.

Sommaire

A Civilian Prototype Occupational Projection Model Using Arena

Stan Isbrandt, Fariya Syed ; DGMPRA TM 2010-015 ; R & D pour la défense Canada – DGRAPM ; août 2010.

Bien que le ministère de la Défense nationale (MDN) possède une longue histoire dans le domaine de la modélisation des groupes professionnels militaires, la simulation et la modélisation des groupes professionnels civils n'ont pas atteint le même niveau de développement. Le présent document décrit un premier prototype basé sur les projections faites pour un groupe professionnel particulier au sein du MDN, c'est–à–dire le groupe des Achats et approvisionnement (PG).

Au sein du groupe du Sous–ministre adjoint (Matériels), le Bureau de la gestion des communautés désirait que des projections de modélisation soient faites pour le groupe PG. On y voyait l'occasion de mettre au point un prototype permettant de gérer une véritable situation d'intérêt tout en montrant la voie menant à la mise au point d'un éventuel outil de modélisation plus robuste pour les groupes professionnels civils. Ce document contient des descriptions illustrant comment le modèle simule la circulation des individus au sein de la structure PG au fil du temps, ce qui permet de produire des projections pour l'avenir. Deux scénarios sont analysés. Premièrement, un scénario dit « du statu quo » , où les nombres d'établissements pour les niveaux PG demeurent constants. Deuxièmement, un scénario dit « de croissance », où les nombres d'établissements pour les niveaux PG augmentent progressivement au cours des cinq premières années. Quelques résultats d'exemples représentatifs illustrant les projections sur une période de 20 ans sont présentés.

On retrouve également quelques « leçons retenues » dans le cadre de la mise au point du prototype et des précédentes analyses de modélisation des groupes professionnels militaires. De plus, certaines personnes ont suggéré de présenter « les étapes suivantes » afin d'illustrer de quelle façon les efforts pourraient se poursuivre vers la création d'un outil de modélisation des groupes professionnels civils plus générique.

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Acknowledgements

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1 Introduction

Like many organizations, the Canadian Department of National Defence (DND) is facing challenges in recruiting and retaining a sustainable workforce over the next decade. One way in which DND can address those challenges is by modelling civilian occupational groups to project their characteristics into future years, and to use these projections to evaluate options for managing the occupations over time. While DND has a robust history of proven success in the modelling and analysis of its military workforce, it has not yet focused on using a similar methodology to model the civilian workforce. To effectively meet the challenges of civilian human resource management, DND is attempting to leverage its success in modelling military occupations to modelling its civilian workforce.

Occupations in the Canadian Public Service are classified into occupational groups, with levels within each group. One group within DND that is facing particular challenges with regard to recruitment and retention is the Purchasing and Supply (PG) Group within the Assistant Deputy Minister (Materiel) (ADM(Mat)) Group. DND is formalizing the career management of PGs through community management in an attempt to expand the community in the coming years, despite the fact that a significant portion of the current workforce will become eligible to retire. The challenge of expanding a workforce with the necessary skills and experience is exacerbated by a significant gap in the distribution of experience and age due to government downsizing in the 1990s.

A chart showing the age distribution of the individuals in the PG group in 2006 is shown in Figure 1. The data points represent a histogram of the numbers of individuals, grouped by five–year age bands. The legacy of the downsizing period is evident in the trough around the age bands for the ages 30–34 and 35–39. Also, over the past five years there have been significant structural changes to the PG classification, where positions were reclassified to different levels. For example, a large proportion of the PG group at level 3 was converted to level 4. This complicates the projection of historical movement within the PG classification into the future. Figure 2 shows historical annual changes to the PG population by level. Even though there has been significant growth in the PG population over time, there is still an expectation that it will be difficult to meet future demand, in part due to an increasing requirement for PGs, but also due to the aging demographic leading to an increased number of retirements.

DND undertook a project to adapt its military workforce model [1], [2] to the PG group. This project brought together the efforts of personnel responsible for military workforce modelling, the Materiel Group, and Assistant Deputy Minister (Human Resources–Civilian) (ADM(HR–Civ)) personnel. Modelling of the PG group was the first attempt in recent years to adapt military modelling to the civilian workforce. Therefore, this project serves as a prototype for the modelling of other civilian groups. The capability to model and analyse its civilian workforce can greatly enhance the effectiveness of civilian human resources management. The sustainment of civilian groups that are adequately trained, experienced, and certified is essential if Canada is to meet current and future Defence commitments.

This paper will outline the efforts of the DND to adapt a military workforce model to a civilian occupational group. The preliminary model design will be described, followed by model

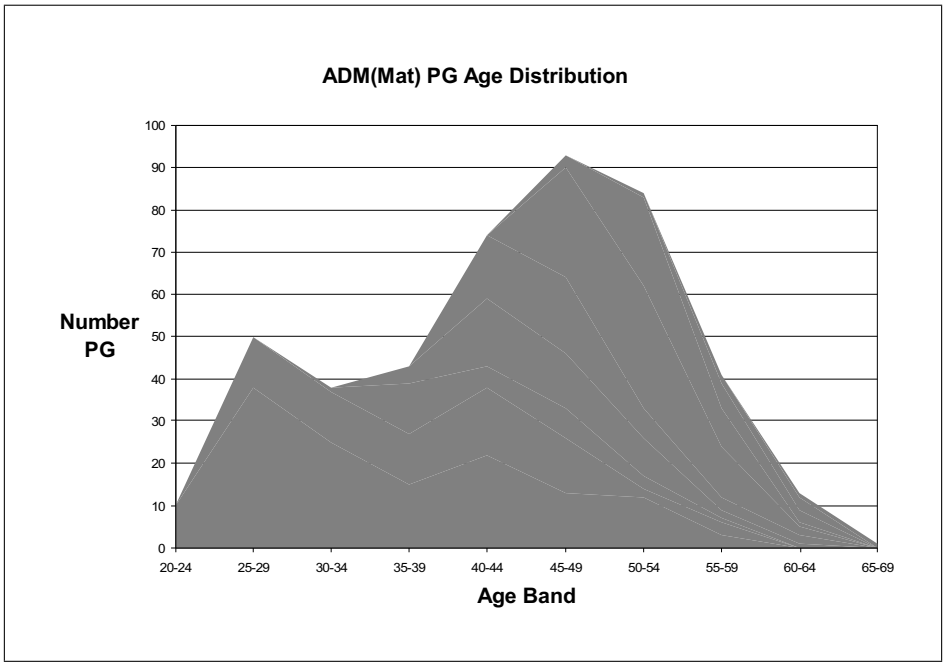

Figure 1: PG Age Profile

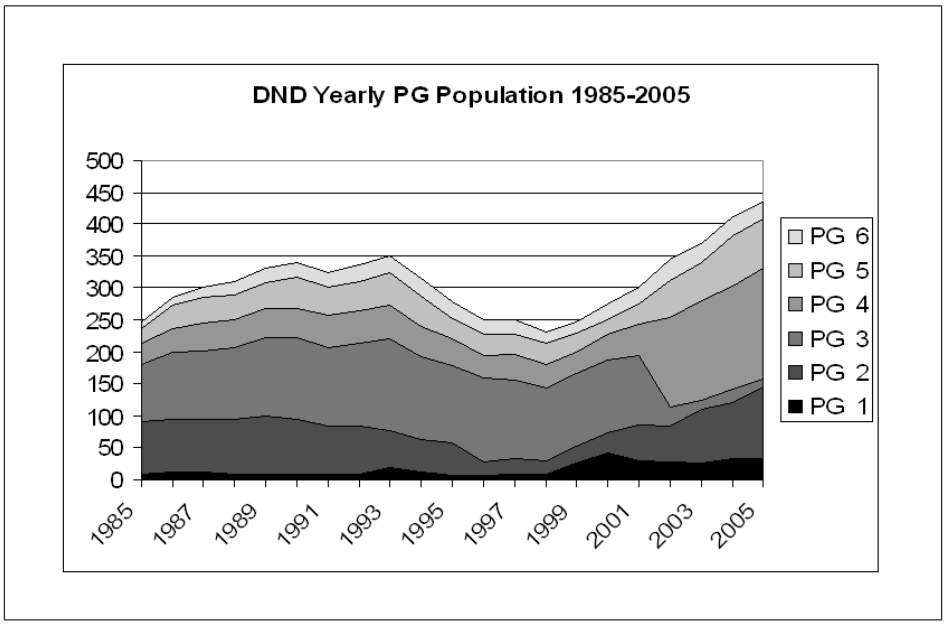

Figure 2: PG Population 1985-2005

implementation, structure and flows of the PG group, and the results of preliminary runs of the model for the PG group. Since it is directly relevant to this paper, much of the previous work described in Reference [3] is included here.

Lessons learned, from both this modelling prototype, as well as from previous similar military occupational modelling, are also presented. These incorporate suggestions having to do with various aspects related to modelling and analysis, including observations regarding input data used by a model, and refinements to a model resulting from a series of interactions with a client who will benefit from the analysis results.

Future steps are recommended at the end of the paper, as this project was intended to be the beginning stage in the development of a corporate civilian occupational group modelling capability.

2 The Prototype Model

A need to model the PG classification originated with a requirement from the Community Management Office (CMO) within the ADM(Mat) Group. The majority of PGs in DND are in ADM(Mat), and CMO manages the PG classification within DND. The CMO foresaw possible medium- to long-term management issues within the PG group, which they wanted to address by modelling the evolution of the group.

In the past, the possibility of implementing a civilian modelling capability within the ADM(HR–Civ) group had been considered. It was decided to explore the possibility of a generic civilian modelling capability by developing a PG occupational simulation model. This project was proposed to the ADM(HR–Civ) Management Team in 2007, and accepted as a trial project to explore the feasibility of a modelling capability for the civilian workforce.

There were similarities between requirements for the PG model and features available in an existing generic military occupational model implemented in Arena [4] . The similarities included the following:

a. Individual members in an occupation are grouped in levels and can be promoted from one level to another;

b. Factors that affect the "flow" of members into, out of, and within an occupation, such as leaving patterns, entry into the occupation, and promotion within the occupation, can be represented using similar modelling mechanisms; and

c. Many of the individual member attributes that could be used in a PG model were similar to attributes already in use in the military model.

Moreover, there were clearly some differences between what was needed in a PG model and what was provided in the existing military model. The underlying structural differences relate to the degree of career management. Military careers are subject to tight controls such as obligatory service periods, minimum time in rank, mandatory qualifications before promotion, and restrictions on reclassification between occupational groups. PG members, unlike military members, are free to compete for advancement on an individual basis, with no existing formal certification of qualification for advancement. They are measured against a Statement of Qualifications associated with a particular position. One obvious difference identified immediately was the fact that in the military, individuals go only to the next higher occupational level (rank) when promoted. In contrast, in civilian groups like the PG group, there is a small but significant flow where individuals are promoted to the second higher occupational level, i.e. two levels up. Also, the military typically recruits inexperienced members at the lowest levels, while inflow to the PG group is basically at any level, with existing experience and pension credits. Leaving rates in the military are strongly correlated with years of service, while PG members have a weaker correlation between propensity to leave and both age and Pensionable Years of Service (PYOS), resulting from the applicable pension plan. Both the career management and modelling of military personnel are conducted at the national level; however, civilian employees are recruited and career-managed at lower level organizations but, once hired, can move between

organizations (examples are at the government departmental level or department members within a specific geographical region of Canada). This complicates the question of which is the relevant population to model and gather data on.

In order to assess the various adaptations that would have to be implemented, an analysis of historical data was undertaken, and the client organization involved with PG hiring, occupational policies, and training programs was consulted. The historical data analysis provided information from which to derive the "flows" typical to the PG group. These flows include items such as the following: historically, what proportion of promotions to a given level come from one level below, as opposed to two levels below, and what proportion of members filling vacancies at a particular level have come from other sources (e.g. university graduates, other government departments, etc.) rather than from promotions within the occupational group.

The flows derived from historical analysis were discussed with the CMO, both as a means of verifying correctness of the analysis, and also as a starting point for discussions on whether there were any reasons to believe that future occupational flows might be different from historical patterns. An example of the latter is the intention of the client group to implement a "trainee" program within the group to help offset possible future shortages during a planned expansion phase. This training program would prepare entry-level PG individuals for mid-level positions over a two-year time frame.

2.1 PG Occupational Structure and Flows

The PG group is nominally composed of levels 1 (junior) through 6 (senior). Feeding into the PG 4 level there are two separate streams, one a "fast track" training stream entering from the PG 3 level, and the other a working stream which feeds in from the PG 2 level through a competitive process. In DND level 3 has essentially become a training level, some of the level 2 positions are used for training that feeds into the level 3 trainees, and the remainder of the level 2s are regular working level positions. For the purposes of the PG model, seven groupings are used, with the PG 2 trainees grouped independently from the regular PG 2 working level. So, the ordering of levels from junior to senior is represented as PG 1, PG 2, PG 3, PG 4, PG 5, and PG 6. For modelling purposes, the PG 2 trainee members are modelled in a portion of the PG 2 level labelled as PG 2T. Also, to indicate that the level 3 members in DND are part of a trainee stream, their level is labelled as PG 3T. The occupational flows, entry, promotion, and departure are represented in Figure 3.

"Pull" flows represent promotion flows where a member can move from one level to a higher level only on winning a competition to fill an empty post at the higher level. This is the normal mechanism for career flow advancement for most members.

"Push" flows represent promotion flows where a member automatically moves from one level to a higher level under certain conditions. In the scenarios modelled, there is a trainee stream that uses push flows. This training mechanism is seen as one possible means to alleviate the expected future pressure on maintaining the PG occupation in the department. Within this training stream, PG members are modelled as being recruited directly into level 2, shown as PG 2T in Figure 3. After

one year, they are "push" promoted to level 3 (shown as PG 3T in the Figure). After one more year of training, they are again "push" promoted to level 4.

Individual recruits can enter at any level from outside of DND provided they compete for and win a position, and similarly they can retire from any level or resign from DND to take a position elsewhere.

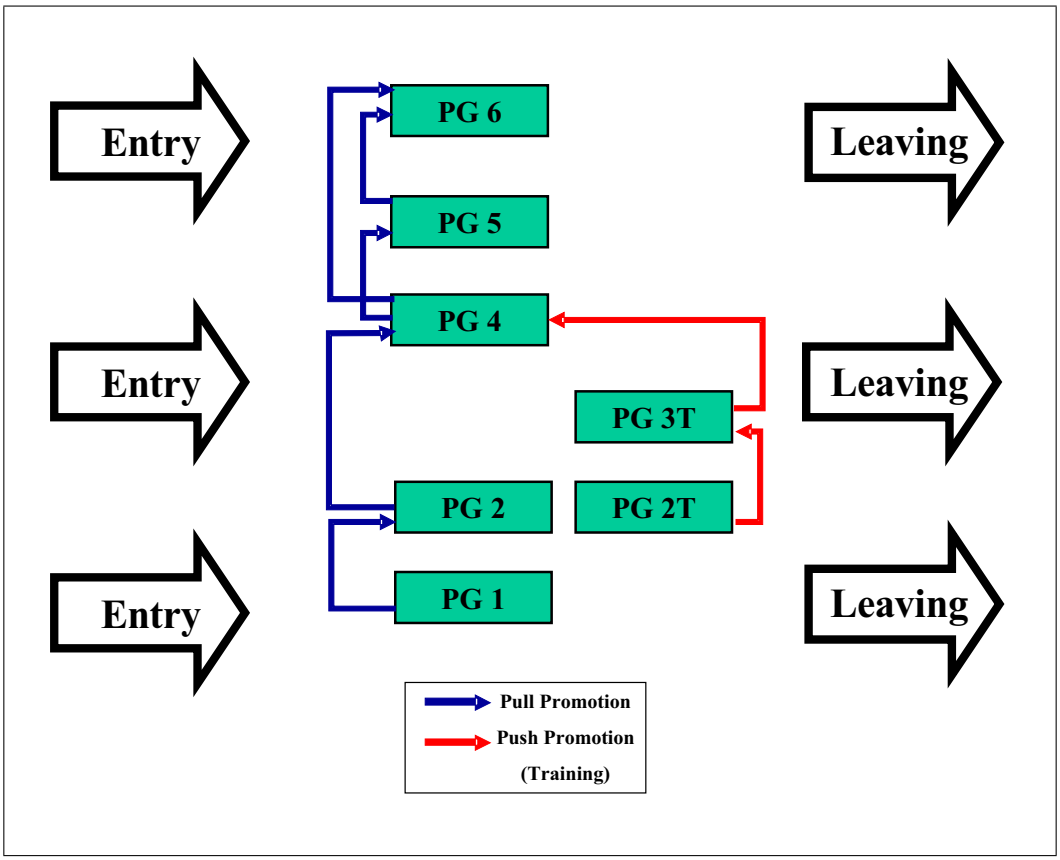

Figure 3: PG Occupational Flow Patterns

Departure rates used by the model are shown in Figure 4. The rates are historical (2000-2006) proportions of individuals in cells defined by age and PYOS bands, who leave the PG group each year. In the model, a rate is used in conjunction with a "coin flip" for each individual in each simulated year, to determine whether that individual leaves or not. So, for instance, someone with 17 PYOS and who is age 47 would have a 0.06 or 6% chance of being sampled to leave in any simulated year. Data for ages above 65 was sparse, so an assumption was made to use the value 0.5 for such cells, to reflect the fairly high leaving rates associated with an increased likelihood of retiring compared to younger ages. Departure rates are a combination of retirement and resignment rates. Ideally, such rates would be specified by exact age and PYOS values, but not enough data was available to determine such values with accuracy. In fact, data from three similar groups (PG, Administrative Services, and Financial Management) were combined (under the assumption that their departure patterns are similar) in order to provide a greater level of detail.

Probability of Leaving by PYOS and Age								
35+					0.17	0.16	0.16	0.50
30-34				0.05	0.12	0.24	0.09	0.50
25-29			0.04	0.04	0.08	0.16	0.32	0.50
20-24			0.05	0.04	0.06	0.08	0.32	0.50
15-19			0.06	0.06	0.05	0.08	0.14	0.50
10-14		0.07	0.08	0.05	0.07	0.07	0.38	0.50
5-9		0.11	0.08	0.03	0.07	0.12	0.13	0.50
0-4	0.08	0.10	0.08	0.25	0.08	0.04	0.00	0.50
	<25	26-35	36-45	46-50	51-55	56-60	61-65	65+
PYOS	AGE							

< 0.08 >= 0.08

- Based on PG, AS and FI categories as a group
- 65+ assumed to be 0.5 due to low sample size

Figure 4: PG Leaving Probabilities

Promotion flows that are modelled when vacancies are available at the destination level are: PG 1 to PG 2, PG 2 to PG 4, PG 4 to PG 5, PG 5 to PG 6, and PG 4 to PG 6. The PG 1 and PG 2T levels are filled from entry outside of the PG group, when vacancies are available. The PG 2T members are "push" promoted to PG 3T after one year, and the PG 3T members are "push" promoted to PG 4 again after one year. All levels are sampled for "departures" each year, with the likelihood of leaving based on age and PYOS as described previously. Except for the PG 3T level, any shortfalls after promotions are made are filled by "entry" members coming from outside the group. (This scheme for filling shortfalls was used in the prototype model scenarios, but it is recognized that realistic scenarios may need to use different assumptions that could result in a shorfall sometimes not being completely filled.)

Movement into and within the DND Materiel Group PGs is shown in Figure 5, except for "push" promotions for the trainee levels, which were modelled to always happen at the planned time. When the model has vacancies to fill during a simulated year, the rows shown in this figure list the possible sources of individuals to fill the vacancies, as well as a sampling distribution showing how individuals are sampled to come from each of the sources. The row illustrating "Promoted To" for PG 6, as an example, indicates that sampling takes place to reflect an historical pattern that 10% of the entries would be promoted from the PG 4 level, 80% from the PG 5 level, and 10% would come from a source external to DND.

2.2 Model Implementation

The model implementation begins with a "current population" that is read in from an Excel file. This starting population is represented as one row of data for each individual in the occupation, with columns representing various attributes used in the simulation. The initial prototype model

Promoted To	Promoted From						
	PG 1	PG 2	PG 2T	PG 3T	PG 4	PG 5	External Entry
PG 1							1.0
PG 2	0.2						0.8
PG 2T							1.0
PG 3T							
PG 4		0.7					0.3
PG 5					0.7		0.3
PG 6					0.1	0.8	0.1

- **External Entry vs Promotion from Within**
- **Push Promotions (2T to 3T, and 3T to 4) not Included**
- **Data From Mar 2006 Mobility File**

Figure 5: PG Promotion Likelihood

has attributes for the member's level in the PG group, their Time in Level (TIL) in years, their PYOS, and their age. Using the Arena simulation software application [4], the design of a model allows for easy inclusion of other attributes, if they are deemed to be useful as the project proceeds.

The starting population is projected to reflect the net result of various mechanisms affecting the occupational group over the course of one simulated year. First, all members of the occupation are sampled with a random "coin-flip" and compared to a departure distribution defined by age and PYOS. There is a training submodel that simulates the assignment of training courses to individuals, but this was not used in the prototype model, since the primary focus was on occupational career flow without taking into account any training flow constrictions. Once the leaving members have been accounted for, both promotions and entry are simulated to represent the filling of vacancies created. In the prototype model, it is assumed that all vacancies are filled, using historical proportions of members promoted from within, as well as members created to represent the entry of new members from outside of the PG group. New members created are assigned age and PYOS values consistent with historical patterns, as described below. Some of the promotions are automatic "push" promotions, which are enacted even if there is no shortfall at the destination level. These "push" promotions are enacted before any other promotions or entries are simulated to fill positions left vacant by members leaving. The model records numerous observations both during the flow of members through the processes just described, as well as in another reporting phase, enacted after these processes are completed.

As the simulation needs to create new members, they are first assigned a PYOS depending on the PG level which they feed into, and then an age. The cumulative distributions used to generate PYOS values for new members in the simulation are represented in Figure 6. PG 3T members are not included in the figure, since they are not explicitly created as entry members during the simulation, they are only created by promotions from the PG 2T level.

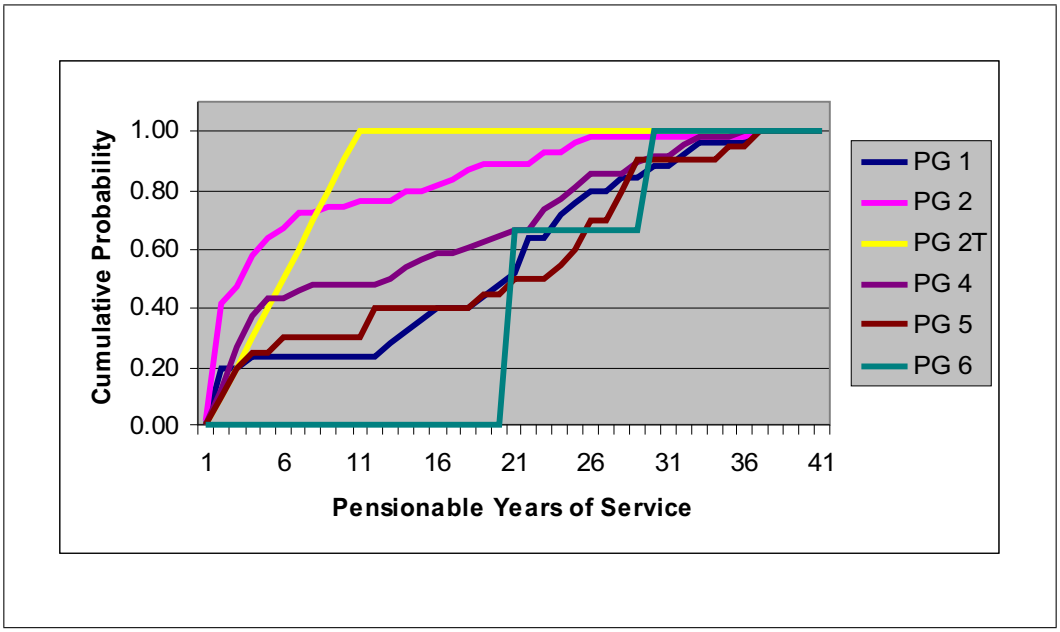

Figure 6: PG Cumulative PYOS Distributions for Entry Members, by Level

Depending on an entry member's assigned level and PYOS, they are assigned an age from either a Triangular or Uniform probability distribution, according to Table 1. The age assignment was based on general "ball-park" estimates derived empirically from existing data, and was judged suitable for the prototype model. If the modelling were to be refined for a serious analysis of the PG group, a more thorough study of the PYOS and age assumptions for simulated members would be warranted.

The Arena implementation of the PG model is shown in Figure 7. The model was purposely designed to correspond closely to the occupational flows illustrated in Figure 3 above. The top-level blocks shown here are submodels that contain more detailed model mechanisms. For instance, the block labelled "PG 4" has internal mechanisms that simulate members leaving according to a probability distribution, those being promoted, those entering as recruits, and also allows for an "aging" process as a simulation is run (i.e. appropriate values such as PYOS and TIL are incremented by 1 at appropriate simulated times to reflect the passing of one simulated year).

In order to ensure that model logic is carried out in the proper sequence during the simulation process, a separate timing chain generates signals used in conjunction with holding queues. This coordinates the movement of individuals through the occupational levels. In the prototype, the model logic strives to maintain the number of members at each level equal to a predetermined number of positions allocated for that level. It is important, for instance, to sample members leaving a level of the occupation before promoting to or from that level.

When a one-year cycle has been simulated and the various results recorded, the "end state" of the population then becomes the beginning state for the next simulated year. In the prototype model, each simulated run projects forward through a 20-year period, and 20 runs are made in order to get a sample of results for reporting purposes and statistical analysis.

Table 1: PG Group New Entry Members Assignment of Age Based on PYOS

Level	PYOS	Age Sampling - Random Distribution Used
PG 1	PYOS < 10	TRIA(43, 44, 49)
PG 1	10 <= PYOS < 20	TRIA(43, 48, 56)
PG 1	20 <= PYOS < 30	TRIA(40, 46, 52)
PG 1	30 <= PYOS	TRIA(54, 54, 60)
PG 2	PYOS < 10	TRIA(30, 34, 55)
PG 2	10 <= PYOS < 20	TRIA(37, 45, 56)
PG 2	20 <= PYOS	TRIA(42, 47, 56)
PG 2T	All PYOS	UNIF(20, 35)
PG 3T	Not Applicable	Not Applicable
PG 4	PYOS < 10	TRIA(38, 40, 52)
PG 4	10 <= PYOS < 20	TRIA(42, 48, 52)
PG 4	20 <= PYOS < 30	TRIA(42, 48, 52)
PG 4	30 <= PYOS	TRIA(51, 52, 56)
PG 5	PYOS < 10	TRIA(36, 37, 40)
PG 5	10 <= PYOS < 20	TRIA(35, 40, 44)
PG 5	20 <= PYOS < 30	TRIA(44, 49, 54)
PG 5	30 <= PYOS	TRIA(52, 53, 54)
PG 6	All PYOS	TRIA(42, 45, 50)

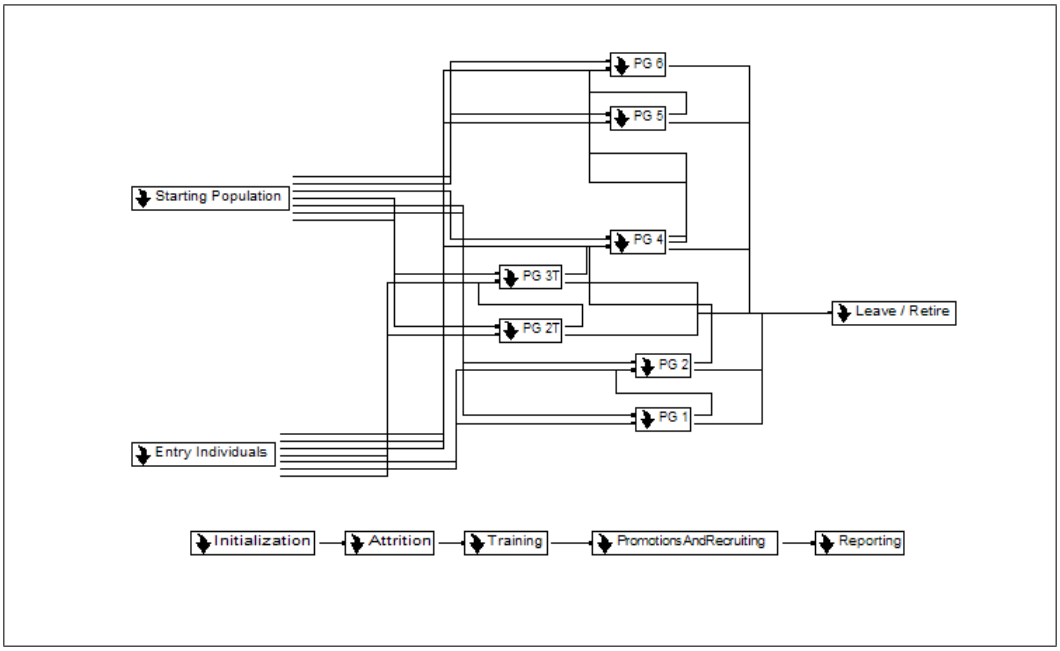

Figure 7: PG Top Level Arena Screenshot

In the model, a "Starting Population" block is enacted only once at the beginning of a simulation run to feed in data representing the current member population of the PG occupational group within DND. Detailed processes (attrition sampling and promotion logic, in particular) are incorporated within each of the PG level submodels. An "Entry" block generates appropriate new members at various levels, when required by model logic. A separate sequence of submodels represents the chain of yearly initialization, the signal generation for model mechanism chronology, and year-end reporting (as explained later on and portrayed at the bottom of Figure 7).

A schematic illustrating the sorts of changes oriented around one level is shown in Figure 8. Individuals can be promoted into the level, or promoted out of the level (this applies to individuals in DND for this model application). Individuals from outside of DND can enter the level (shown as a lateral arrow in) as hires from private industry or educational institutions, or as transfers or promotions from PG communities in other government departments. They can also leave (shown as a lateral arrow out) on retirement, or to private industry, or as transfers or promotions to other government department PG communities. Within a level, an individual may also be modelled to undertake training. In the figure, "Base Training" refers to mandatory training that everyone in the level is expected to take at some time (e.g. possibly certification training), whereas "Specialty Training" is meant to refer to training that only some proportion of the individuals in a level would be expected to take. The model implementation accommodates training, but the prototype application of the model did not use training although the capability was there.

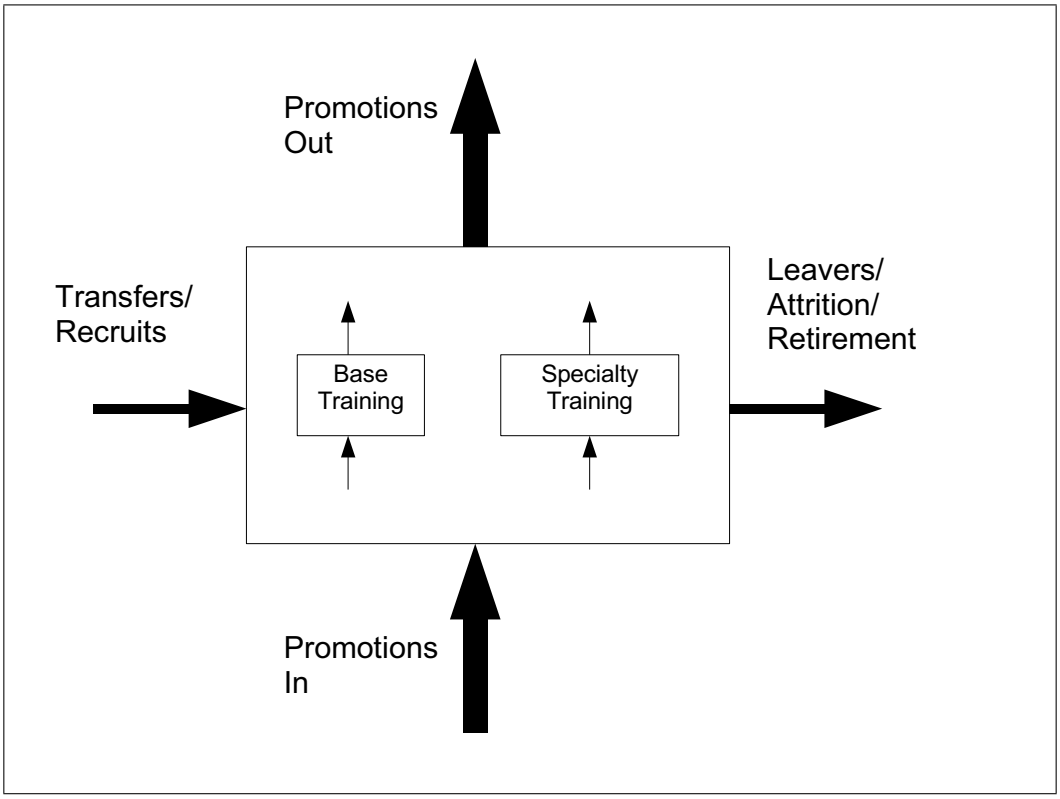

Figure 8: Schematic of Changes at a Level

An alternate schematic illustration of the transitions that can occur to a modelled individual at one level is shown in Figure 9. Here, the changes are shown as a logic flow diagram, similar to the basic logic that is implemented in the Arena prototype model. This representation not only includes the changes shown in Figure 8, but also illustrates the cycle where individuals are "aged" on an annual basis (i.e. attributes such as TIL, PYOS and the member's age are incremented to represent the passing of one model year).

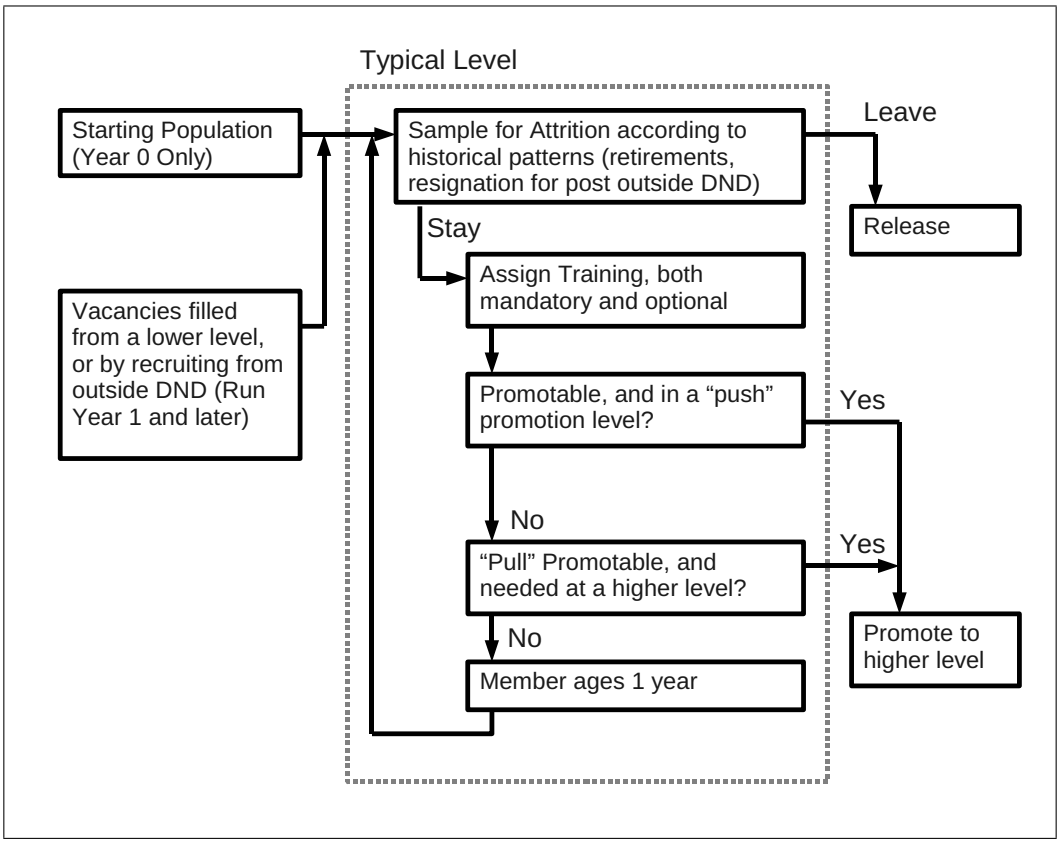

Figure 9: Flow of Typical Level Transitions

In Table 2 the general sequence of modelling events in each simulated year of a model run is portrayed, from the top to the bottom row. First, an initialization of various data elements is carried out. Then, each individual member has a "coin-flip" attrition comparison to a probability distribution, to sample whether he/she leaves that year. Those members who do not leave are eligible for training courses (if they are defined), and possible promotion to fill vacancies at a higher level (if they have a TIL of at least one year). Remaining vacancies in the establishment are filled by recruiting from elsewhere. Finally, at the end of each modelled year, a reporting phase writes out information for subsequent analysis, and the cycle is then repeated starting with attrition, until the final simulation year is completed.

Table 2: Yearly Simulation Sequencing in the Model

Initialization	At the beginning of a simulation iteration, reads in various input files, and records some tombstone information. During an iteration, resets variable and array counters for the start of another simulated run year.
Attrition	Once each run year, sends a signal to the various levels to have them apply a release "coin-flip" to their members, according to input distributions.
Training	Once each run year, after attrition is completed, training is applied to each level.
Promotions, Recruiting	Once each run year, after completion of all training, vacant positions are filled by promotion and then recruitment. "Push"promotions are done first, then, starting from the top level down, regular promotions and recruiting entry are carried out.
Reporting	At the end of each run year, information is written out to various output files. (There are also other reporting functions embedded within level logic that supplement this process.)

2.3 Preliminary Model Runs

Two scenarios were run with the prototype model to provide an illustration of its capabilities. One scenario (Status Quo) projects the current population forward, keeping the established number of positions at each level constant. The other scenario (Growth) represents a "growth" scenario, starting with the same number of established positions, and reflecting a 10% per year proportional growth across all levels for model Run Years 2, 3, 4, and 5, and then keeping the number of established positions constant from the fifth modelled year forward. All other input parameters are kept the same between the two scenarios.

The starting numbers of established positions are shown in Table 3. The "starting" population for the model consisted of 382 individuals, whose attribute values were obtained from the 2006 DND Human Resource Management Information System database.

Table 3: PG Group Established Positions

Level	Established Positions
PG 6	30
PG 5	74
PG 4	142
PG 3	15
PG 2T	15
PG 2	78
PG 1	28

There are many model results that can be examined to explore the impact of the Growth scenario compared to the Status Quo scenario. As two specific examples, we will examine overall recruiting patterns between the two, as well as average TIL values for the PG 2 and 4 levels. The results are illustrative of the kinds of information that can be determined from the modelling prototype, and many more similar results for a number of different outputs can be portrayed from the simulation runs.

In Figure 10, the patterns of total releases, averaged over 20 simulation runs, are graphed for both the Status Quo and Growth scenarios. Since both scenarios begin with the same number of established positions at each level, the values for Run Year 1 are identical for both cases. As the number of established positions for the Growth scenario increases, then there is an increased number of releases resulting from the larger population. Under the model assumptions used for the scenarios, we can see that when things settle down after the growth period, there is a constant number of releases, averaging close to 55 members leaving each year. This is in contrast to the Status Quo scenario, which generally has around 38 members leaving each year. Since this model assumes there are always enough entry members to fill vacancies, the number of releases each year is equal to the number of entry members taken in, with the exception that in the Growth scenario there are extra entry members needed during the years when the number of established positions is increased.

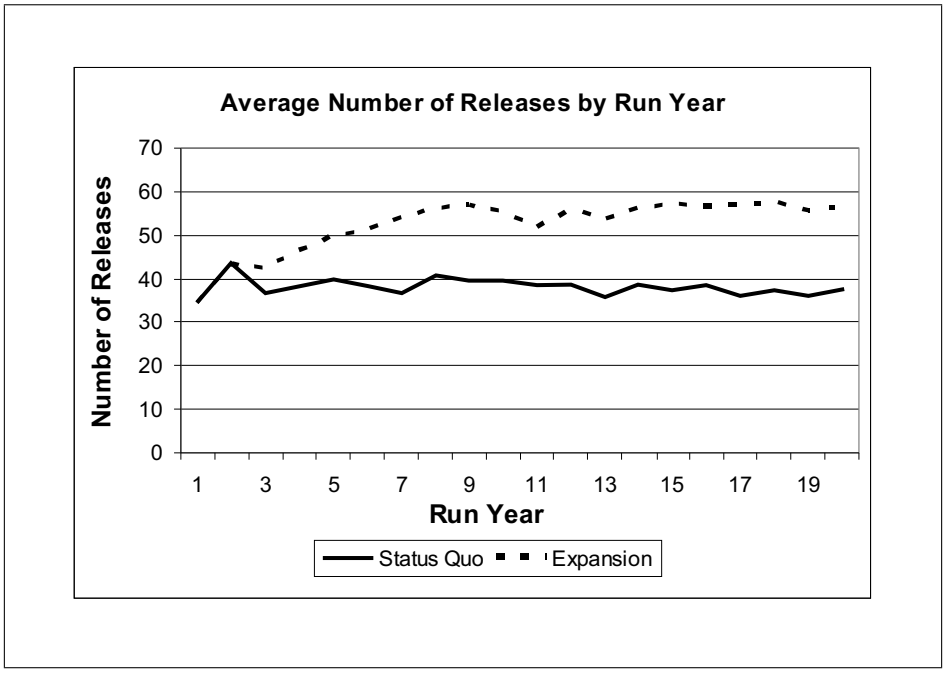

Figure 10: Average Entry by Model Run Year - Status Quo and Growth (Expansion) Scenario

The releases and entries can also be examined by individual PG levels over the simulation period to assess the impacts of entry requirements. If, for instance, the expected number of PG 4 entrants during the growth phase of the Growth scenario was considered to be unrealistic, then an alternate growth scenario might be considered to be more practical, such as perhaps expanding the trainee stream entering at the PG 2T level. An increased number of PG 2T trainees would automatically

result in a higher number of the trainees "graduating" to the PG 4 level two years later, thereby reducing the number of entries needed to go directly into the PG 4 level. Of course, this could have other consequences, such as a need to expand the training pipeline for the trainee program.

The simulation results for PG 2 TIL values are shown in Figure 11. Expansion of establishment positions that have taken place in the last few years has resulted in a low average TIL for the PG 2 level persisting at Run Year 1. In the Status Quo scenario, the freezing of establishment positions results in a consistent increase in TIL through about Run Year 10, followed by a smaller rate of increase after that point. From the beginning of the modelled period through to the end, the average TIL value more than doubles. This amounts to a significant increase in average experience for members at the PG 2 level. The Growth scenario also has the average TIL values for PG 2s more than doubling over the same time period, but has lower TIL values than the Status Quo scenario from Run Year 3 through the following 10 years. As the expansion in positions takes place, the significant number of new entrants keeps the average TIL values low for a few years, and the eventual increase in TIL values visibly lags behind the Status Quo scenario until around Run Year 13. Accordingly, although the Growth scenario provides more PG 2 members in the workforce, for a significant time period their experience, as characterized by TIL, is less than that which the Status Quo scenario would provide. By examining average TIL projections of varying growth scenarios, management can develop a better appreciation for sustainable growth rates that maintain a minimum level of experience in the workforce.

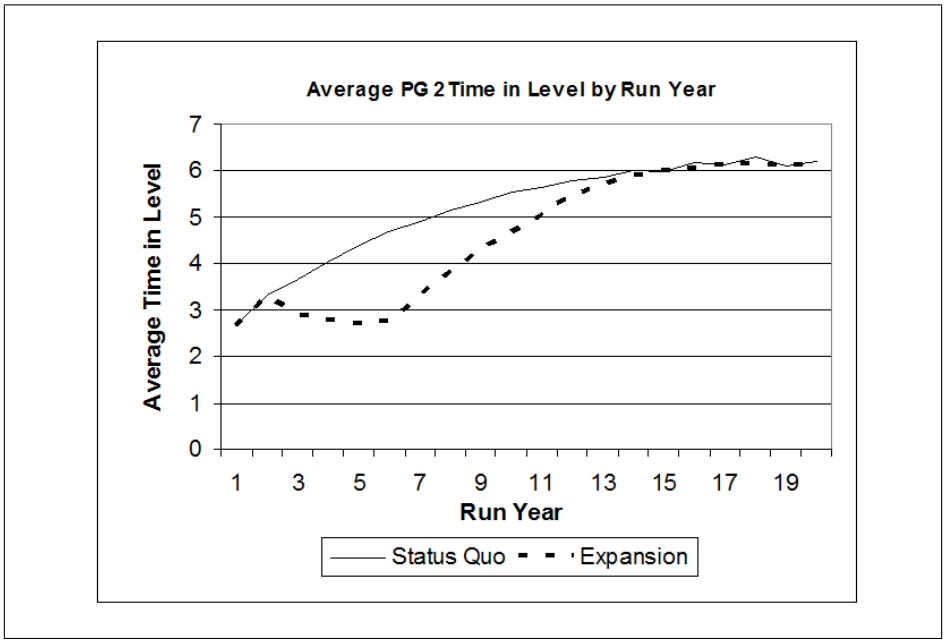

Figure 11: PG 2 TIL by Model Run Year - Status Quo and Growth (Expansion) Scenario

An example of a similar portrayal of simulated TIL for the PG 4 level, but with more details, is shown in the next two Figures.

For the Status Quo scenario, Figure 12 shows three lines graphed over 20 simulated run years, with the middle line representing the median TIL by run year, the top line indicating a 90th percentile,

where 90% of the iterations had an average TIL less than or equal to the values of the line, and the bottom line showing the 10th percentile, where 10% of the iterations had an average TIL equal to or less than the line values.

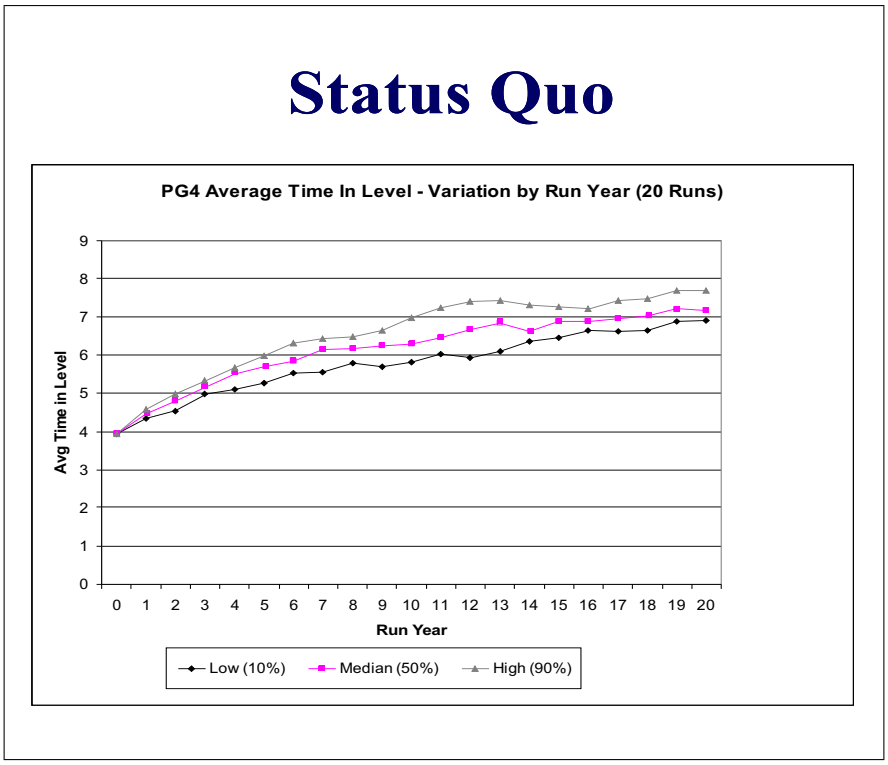

Figure 12: PG 4 Time In Level - Status Quo Scenario

Similarly, for the PG 4 TIL in the Growth scenario, Figure 13 shows the median, 90th percentile, and 10th percentile lines for average TIL.

In the model, it is assumed for most levels that PGs are promoted and/or recruited each year to replace individuals who in turn were promoted or left any particular PG level. This assumption amounts to "inflow" equals "outflow", or, in other words, the number of individuals who enter any level over one simulated year is always equal to the number who leave.

In the prototype model, the two exceptions to this are:

a. Any level where "push" promotion is used, and

b. Any bottom-level entry that is defined differently from what is needed for simple replacement of departing members.

In the Status Quo scenario, the number of individuals maintained for each level is constant as shown in Table 3, so the variation in required entry in the model runs is basically the random variations associated with sampling those who retire from probability distributions, as well as randomness involved with possible entry paths to a level (i.e., promotion from below as opposed to

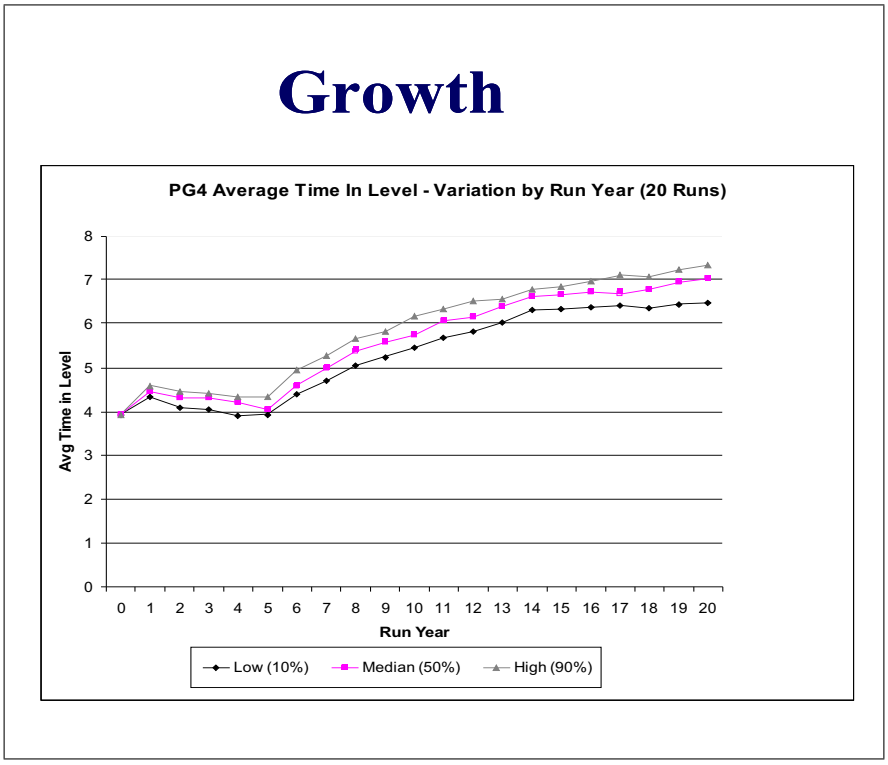

Figure 13: PG 4 Time In Level - Growth Scenario

entry from outside). The age profile demographics of the individuals comprising the PG group also affect the patterns. Figure 14 shows the Total Entry Requirements (i.e., entry over all PG levels), with median, 90th percentile, and 10th percentile results, for 20 iterations over 20 simulated run years. Typical entry requirements range between 35 and 40 individuals a year, with the percentile bands giving an impression of the expected range of variability in the results.

In the Growth scenario, all of the establishment numbers from Table 3 are increased by 10% for each PG level, for model Run Years 2 through 5. In all other respects, the two scenarios are identical. As the establishment numbers grow in this scenario, the entry levels correspondingly increase to accommodate this growth, and then eventually settle down to a steady pattern. The results illustrating this are shown in Figure 15. Again, the Total Entry Requirements are shown with median, 90th percentile, and 10th percentile results. The large magnitude of the required growth in entry is quite evident, even with the randomness illustrated in the variability among the percentile lines, with an eventual, more steady entry pattern settling down to a range encompassing an average of around 55 individuals per year.

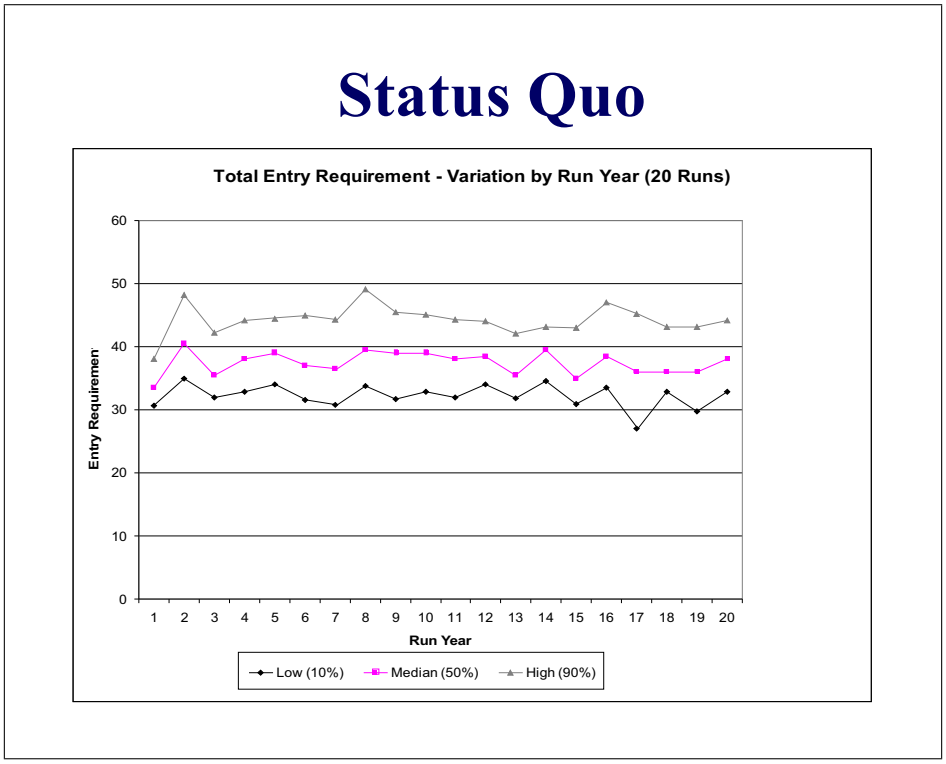

Figure 14: PG Recruiting Requirement - Status Quo Scenario

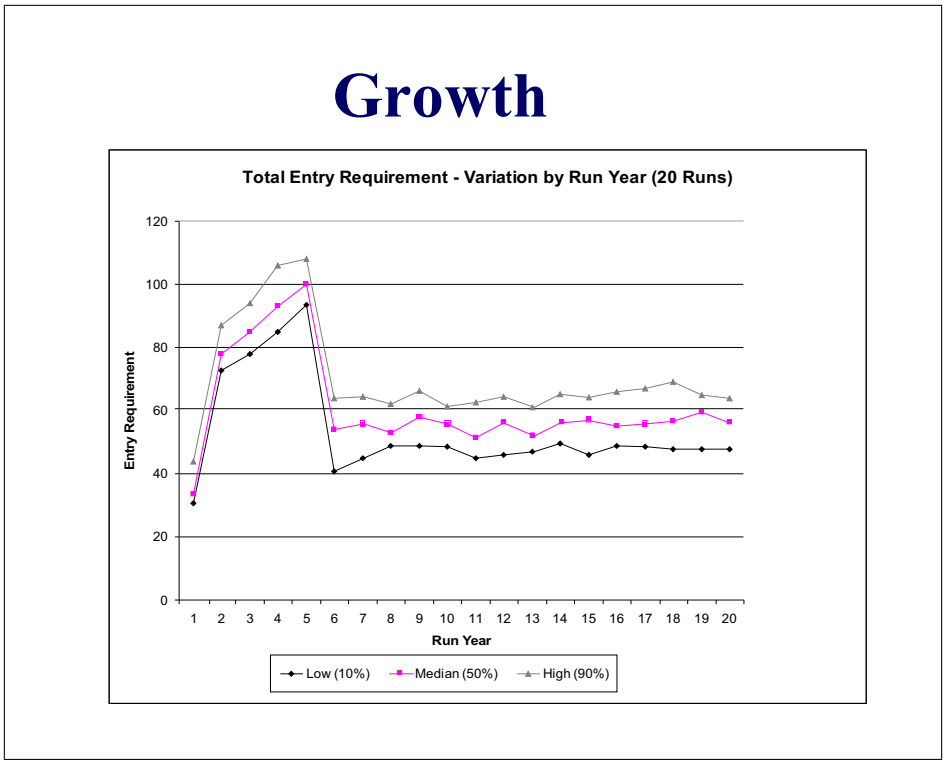

Figure 15: PG Recruiting Requirement - Growth Scenario

3 Lessons Learned

During the course of the prototype model development process, as well as in previous military occupational modelling exercises, it was possible to note specific observations that may be useful to the endeavour of creating a general purpose civilian occupational modelling tool. These observations are listed below, as a series of mostly independent items.

3.1 "Straw Person"

Clients often do not have familiarity with modelling and simulation. One development approach that seems to work fairly well is to have preliminary discussions with a client about occupational management issues they would like to explore, the parameters of the occupation they manage (flows, numbers maintained at various levels, growth vs. status quo, etc.), and generally how a simulation model works. After the preliminary discussions, modellers create a first model, the "Straw Person", run the simulation, and analyse the results. When these first results are briefed to the client, the understanding of how much or how little they can expect from a model typically becomes much clearer, and the requirements for input parameters for a model become better understood. This can lead to a back-and-forth process where over a few iterations successive models and analyses are reviewed and refined as both analyst and client improve their understanding of each other's perspectives. This back-and-forth process can easily proceed over a period of several months. Typically, both client and analyst have other ongoing projects, and they both may have to obtain and vet information from other sources as well, which tends to stretch out the time for an analysis project. What may actually require one month of analyst time can easily stretch to a few or several months once associated time delays are encountered.

3.2 Data

The modelling of a typical occupation requires some significant data collection and analysis. Many of the data requirements relate to the "flow" into, out of, and within the occupations.

An individual coming into the PG 4 level might come from one of several different places: promotion from PG 2, promotion from PG 3T, transfer as a PG 4 from another government department, winning a competition upon retiring from the military, winning a competition and being promoted from a PG position in another government department, winning a competition and coming in from private enterprise, or winning a competition and coming in after academic studies. Data was not available to determine either the detailed patterns of these sorts of flows into the DND PG occupation, or the characteristics (age, Years of Service (YOS)) of such individuals. Accordingly, much simpler aggregate flow patterns were used for the PG prototype modelling exercise. Reliable data for the more intricate flow patterns could improve the accuracy of a model but might be difficult to obtain. Nevertheless, some data might be available from various sources. For instance, Statistics Canada can apparently provide some longitudinal data on individuals moving through various government departments throughout their career.

Whereas military leaving patterns are highly correlated to YOS, civilian leaving patterns are related to a combination of both age and YOS. The data available for the PG group did not allow

the construction of a fine-grained table of departure probabilities for distinct age and YOS values. This sort of data needs a more concerted analysis effort to determine better tables of probabilities.

It may turn out that analyses using an occupational projection model highlight some data requirements that cannot currently be met. In order to allow more accurate modelling in the future, it then may be necessary to improve data collection methods, to begin collecting some data that is not being collected now, or to obtain data from another source, such as Statistics Canada.

The Director General Military Personnel Research and Analysis (DGMPRA) Workforce Modelling and Analysis Team (WFMAT) has a history of data analyses for military occupations and has developed some analytical techniques such as analysis of leaving rates of a military occupation, by YOS, over an historical time period. It also has techniques for detecting when there is a significant change in the trend for a leaving pattern. This expertise could be applied to civilian historical data to explore the application of these and other analytical techniques to civilian occupations. These sorts of analyses would help, first, to provide demographic representations of an occupation, and second, to provide the input data values needed for a civilian occupational projection model.

3.3 Create a Generic Model from Several Prototypes

When the Arena Career Modelling Environment (ACME) model was developed [1] it was successively trialed on a number of representative military occupations. The model was put through its paces on the Medical Technicians, the Military Police, the Artillery, and several other occupations and occupational groups. The model was successively altered and augmented until it became a good "base" representation capable of modelling a wide range of existing or potential military occupations or occupational groups. The resulting model is essentially a "generic" model that, "out of the box", typically needs only minor changes in order to undertake a typical analysis. The wide range of structure and policy changes explored by the military preclude the possibility of making one definitive "all-singing all-dancing" model. Accordingly, the generic model, which already meets 90-99% of the modelling requirements, and usually only needs minor tweaking, has worked well for occupational analysis in the military setting.

The success of this approach suggests that a similar strategy could be used to create a civilian generic model. By modelling a series of civilian occupations, a reasonable base model can be progressively improved to create a more comprehensive model that "out of the box" meets 90-99% of civilian occupational modelling requirements. Then, similar to the way in which the military model is used, it could be tailored, as appropriate, for specific analyses.

3.4 Precision

By its nature, the monte-carlo simulation modelling discussed here cannot provide "two-decimal place" exact projections. Rather, trend information is produced, based on input data and modelling assumptions, with the capability to provide some idea of how much variation can be expected around the trends. In some occupations, it may well be the case that career managers can provide a better short-term projection than the models, since they are continually in touch with individuals in the occupation. However, when making projections for 3 to 5 years into the future

and beyond, a well-designed model does a better job of combining the various intricacies involved, including demographic projections, to provide more robust overall trend information than is otherwise available.

In some cases, there may be reason to believe that some critical modelling input parameters will be different in the future than they were in the past. Naturally, the model cannot foretell what their exact values will be. However, it is possible, based on subject matter expertise, to carry out a sensitivity analysis on the parameter values. For instance, say that there was good reason to believe that future leaving patterns would be different with respect to age distribution. By modelling with "best guess", as well as pessimistic and optimistic scenarios, some insight can be gained with respect to how much influence the age distribution has on modelling results. If the various scenarios provide results that are basically the same for all scenarios, then the possible variation in input parameters is not very significant. If the various scenarios provide results that are drastically different, then it may be important to try to refine the input parameters (perhaps by surveying individuals' future intentions), or, if that is not possible, to monitor trend information so that revised input parameters can be used in future modelling runs to provide improved projections as time goes on.

3.5 Model Representation of Occupational Flows

Within the WFMAT, responsibilities for modelling can shift from one analyst to another, particularly in response to (or as a result of) personnel postings. Accordingly, there is value in having a model structure that eases the process of indoctrinating and training new individuals to learn a model thoroughly, so as to be able to make modifications as appropriate for new analyses. In both the ACME generic model, as well as the PG group prototype model, the Arena model structure was oriented around the main personnel flows. In the PG model, these were the flows into, between, and out of the various PG levels modelled, as pictured in Figure 7. Submodels representing occupational levels were used as the main model structures. The processes within a level, such as sampling those who leave in any given year or who accept promotions from a lower level, are represented as other modelling structures contained within the main level structures. This hierarchical layering of model structures, oriented around the principal flows being modelled, provides a natural connection between the conceptual view of how individuals in an occupation go through various transitions, as represented in Figure 3, and the model structures used to represent these flows in the prototype model.

3.6 Output Everything

In the PG civilian prototype model, as well as in previous military occupational modelling, extensive, detailed output is written to files as a simulation run proceeds. Essentially all transitions involving individuals are recorded, even though very large output files may be created. In the prototype model, these output files are post-processed, in an automated fashion, to make a number of predefined charts for analysis purposes. However, there can always be some instances where the predefined charts are not sufficient to clarify all required aspects of an analysis. By having the detailed outputs available, an analyst can "slice-and-dice" the original details in new and different ways. Since all transitions are recorded, there is the possibility of extracting any combination of

detail desired. This can be done, for instance, by importing the data into a Microsoft Access database and creating custom queries to further investigate and understand specific topics of interest.

3.7 Model Basic Flows First

Although the prototype model can accommodate comprehensive training sequences, it is suggested that initial analysis not include training, but rather address the primary flows of entry, exit, and promotions, given the specified establishment requirements that are to be maintained over time. If an occupation cannot suitably sustain itself, considering these more basic elements, then it has some important structural issues that managers need to address. Adding training constraints (e.g. limited course sizes) to an occupation whose structure and flows are not sustainable will not improve the situation. In summary, modelling should be used to first assist in determining the proper parameters for a workable, sustainable, overall occupational structure with healthy flows, and afterwards to look at issues related to training constraints.

3.8 Model Archiving

When using a model such as the one described in this paper for a series of different analyses, it is advisable to have some form of consistent model archiving. Often when an occupation has been analysed under a set of assumptions, a follow-on study may be requested (sometimes years later). With an archive, the model can be retrieved and reused, with the inclusion of appropriate new assumptions and modifications. It may also be the case that a new occupation is to be modelled, which has distinct similarities with another occupation modelled in the past. Again, retrieving the similar model from the archive, and amending it as appropriate, can leverage the effectiveness of previous work done.

Difficulties with model archiving are associated with normal organization transitions such as personnel changes and computer equipment changes. This necessitates a concerted effort to back up and maintain a suitable archive in order to enable model reuse. One possible strategy is to provide some level of archive backup by not only maintaining an archive on-line, but also by having a redundant copy of models on media such as compact disc (CD) or digital versatile disk (DVD). Formally assigning responsibility to one individual for maintaining the archive and media backup may help to alleviate some of these challenges.

4 Next Steps

Before putting significant effort into the generation of a "generic" model, as has been described above, it should be decided whether such a model would be worth the effort in the long run. A certain level of occupational analysis or demographic projection can be done with simpler tools, such as an Excel spreadsheet. Statistics Canada also provides (at a cost) an occupational projection tool called PerSim, which can provide demographic projections of federal civil servants, but is less detailed and does not have the flexibility (in terms of custom analyses) of the prototype model described here.

One limitation that was highlighted with the PG prototype model was the lack of data for some of the parameters needed for setting up an accurate model. If a concerted modelling effort is to be made for the creation of a civilian model, it is also desirable to undertake a more thorough analysis of the civilian data to get better input parameters. Examples of more detailed parameters that would be useful are:

a. More detailed age and YOS breakdowns of leaving rates, including at the retirement stages, and

b. More detailed entry flows (e.g. from other government departments, ex-military entrants, from private enterprise, from university) and similarly more detailed departure flows.

A suggested way forward is to proceed simultaneously with:

a. A sequence of modelling analyses to lead towards a generic model, and

b. To develop more standard analytical processes to generate demographic portrayals and flow parameters useful for modelling.

The analytical processes mentioned in the second point would also be useful for simpler occupational demographic presentations on their own, as well as for providing data to be used within modelling. The analysis results of the various occupational projections would illustrate the potential of the modelling and provide information useful to the decision as to whether this level of detailed modelling is desirable to have and maintain over the long term.

The time period necessary to carry out the model development, along with the supporting data analyses, would be at least a year. Although the effort is significant, the military occupational modelling experience, and the demand for such modelling by clients, suggest that it may well be useful in the civilian context as well. Based on the results of model development and the gains and limitations of employing a generic civilian model, an assessment can be made regarding whether or not this is a good solution for civilian workforce modelling.

5 Conclusion

This paper has presented a prototype Human Resource (HR) model for the PG group that illustrates some of the potential for developing a "generic" civilian occupational projection model. Some sample analysis results, out of many that are possible, have been used to illustrate the capabilities of such a model. It is felt that such a generic model could be readily modified to provide tailored models for a large number of civilian occupational groups.

DGMPRA, with its ACME military workforce modelling capability, has successfully used the concept of a capable generic base model, and customizing it for specific analyses. So far, this seems to work very well. This results from the fact that many of the basic characteristics of Canadian Forces (CF) occupations are very similar. Nevertheless many of the occupations still have some particular aspects that are different, and some of the analyses explore proposed changes to occupation characteristics. So, this philosophy of a base model designed to be customized in various particular "flavours" has allowed the creation of new models, as necessary, in a timely manner. It is felt that a similar approach would be useful for the refinement of a comparable civilian model.

Some observations on a way forward have been made, relating to how development of a civilian occupational progression model might proceed.

The electronic distribution of this paper is on a CD, which also includes the PG prototype model, input files used for the two scenarios discussed, and output files produced by the model runs. A "Readme" file is provided, which describes the locations of the various files included.

References

[1] Isbrandt, S. and Zegers, A. (2006). *The Arena Career Modelling Environment Individual Training and Education (ACME IT & E) Projection Tool.* Technical report, DRDC CORA TR 2006-03, Ottawa Canada: Defence Research and Development Canada – CORA.

[2] Isbrandt, S. (2007). *Human Resource Model Development Using Arena A Beginning Tutorial.* Technical report, DRDC CORA TM 2007-47, Ottawa Canada: Defence Research and Development Canada – CORA.

[3] Erkelens, A., Syed, F. and Isbrandt, S. (2007). *Development of a Prototype Model for Civilian Occupational Group Projections.* CD Proceedings of the 2007 Summer Simulation Multiconference, The Society for Modeling and Simulation International.

[4] Rockwell Software Inc. (2006). *Arena User's Guide*. Arena pro v11.0 ed, Milwaukee, Wisconsin USA: Rockwell Automation.

List of Abbreviations

ACME	Arena Career Modelling Environment
ADM(HR–Civ)	Assistant Deputy Minister (Human Resources–Civilian)
ADM(Mat)	Assistant Deputy Minister (Materiel)
CD	compact disc
CF	Canadian Forces
CMO	Community Management Office
DND	Department of National Defence
DGMPRA	Director General Military Personnel Research and Analysis
DVD	digital versatile disk
HR	Human Resource
PG	Purchasing and Supply
PYOS	Pensionable Years of Service
TIL	Time in Level
WFMAT	Workforce Modelling and Analysis Team
YOS	Years of Service

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Within the Canadian Department of National Defence, a prototype civilian workforce simulation model was developed for the modelling and analysis of one particular occupational group, the Purchasing and Supply (PG) Group. The model was developed to explore workforce modelling techniques for the civilian workforce with the intention of potentially modifying it for analyses of other occupational groups, and eventually producing a generic civilian occupational group modelling capability. This paper outlines the methodology, the determination of occupational characteristics for modelling purposes, preliminary occupational analysis, lessons learned, and a possible way forward for the workforce modelling of civilian groups.

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