



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**OPTIMIZING THE SCHEDULING OF RECRUITMENT
AND INITIAL TRAINING FOR SOLDIERS IN THE
AUSTRALIAN ARMY**

by

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March 2016

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**OPTIMIZING THE SCHEDULING OF RECRUITMENT AND INITIAL
TRAINING FOR SOLDIERS IN THE AUSTRALIAN ARMY**

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Captain, Australian Regular Army
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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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ABSTRACT

This thesis develops a master scheduling program to optimize recruitment into the Australian Army by employment category. The goal of the model developed here is to reduce the man-hours lost awaiting follow-on employment training. The model aims to provide a more efficient planning tool for the annual optimal recruitment dates to achieve the stated goal for all employment categories within the Australian Army. Two scheduling optimization models are developed in this thesis using linear programming. The first model schedules 30 courses to occur within a 14 to 28 day timeframe, while the second model schedules 36 courses. The first model creates an optimal schedule using the financial year 2016–17 (FY16/17) data to allow the Australian Army to be able to plan the year in isolation, not considering the following year's training program. The second model creates an optimal schedule extrapolating the FY16/17 data out to 18 months to allow the Australian Army to consider a longer-term training schedule. The second model is more accurate and achieves shorter wait times between courses. The models developed in this thesis can be adjusted to provide decision support for future training scheduling to achieve minimum wait times for recruits in the training pipeline.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARTC	Army Recruit Training Centre
AWSMG	Army Workforce Supply and Management Group
ECN	Employment Category Number
FY	financial year
IET	Initial Employment Training
LP	linear program
MCT	Marine Combat Training (U.S. Marine acronym)
MOS	Military Occupational Specialty (U.S. Marine acronym)
STIG	Soldier Training and Induction Generator

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I. INTRODUCTION

A. RESEARCH AREA

This thesis develops a master scheduling program to optimize recruitment into the Australian Army by Employment Category Number (ECN). The goal of this thesis is to determine whether it is possible to reduce the wait time between Army Recruit Training Centre (ARTC) and Initial Employment Trainings (IETs) to within 14–28 days and to be able to plan the optimal recruitment dates annually to achieve the stated recruitment target for all employment categories within the Australian Army.

B. MOTIVATION

The current ARTC and IET course scheduling in the Australian Army is a manual process done by hand, in which each position on the following year's ARTC courses are allocated an ECN. This manual process takes several weeks to complete and is affected by human error, which often results in huge delays between courses. This thesis aims to develop a model designed to optimize the course scheduling, thereby removing the need to manually allocate positions in order to save the Australian Army both time and money.

C. DATA AND APPROACH

The data used to develop this model was the financial year 2016–17 (FY16/17) ECN targets, IET and ARTC course dates and paneling limitations, all provided by the Directorate of Workforce Modelling–Army.

The model developed should be able to identify the optimal intake schedule for the year, based on the year's required recruitment targets, to minimize the time between ARTC and follow-on IETs, optimally to between two to four weeks. The model developed will provide the Australian Army with a decision support tool calibrated to FY16/17 data, which can be adjusted to accommodate changes in data and constraints.

This thesis also makes recommendations based on the results of the optimization model.

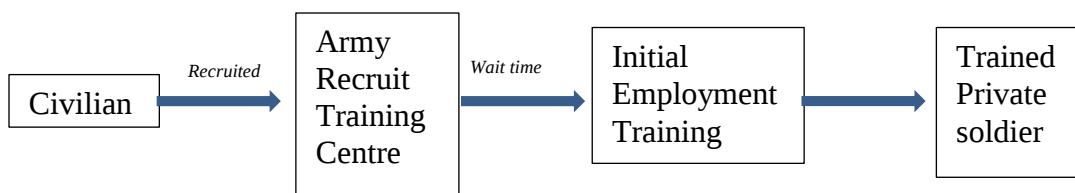
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II. BACKGROUND

A. INTRODUCTION

The Australian Army plans to recruit and train 3,086 soldiers in FY16/17.¹ These soldiers each need to complete basic military training at the ARTC and then complete follow-on, role-specific training called Initial Employment Training (IET). This training is designed so that, on completion, the soldier has the basic skills and job knowledge to work in a specific role as a Private in the Australian Army. The flow from civilian recruit to trained private is shown in Figure 1.

Figure 1. Basic Schematic of Australian Army Soldier Recruitment and Training Process



Adapted from Detar, P.J. (2004). *Scheduling Marine Corps entry-level MOS schools* (Master's thesis). Retrieved from Calhoun <http://hdl.handle.net/10945/1444>.

This thesis' goal is to develop a model and course schedule to reduce the man-hours lost awaiting IET following ARTC for all employment categories within the Australian Army. For the model to correctly incorporate all the constraints, the process by which soldier recruitment and initial training occurs within the Australian Army must first be understood. This process is described in this chapter, along with an outline explaining how that process is currently scheduled, and the issues with that process.

B. RECRUITMENT

The Australian Army has a single entry route for soldiers. They are recruited for specific roles, or Employment Category Numbers (ECNs), through a selection process,

¹ Financial Years (FY) in Australia run from 01 Jul to 30 Jun the following year, hence FY16/17 is 01 Jul 16 until 30 Jun 17.

yet do not become paid members of the military until the date they post to ARTC in Kapooka, New South Wales.

Annually, the Australian Army branch of the Directorate of Workforce Supply Management develops targets of how many recruits must be hired in the following financial year for each role, or ECN. These targets are used as inputs into a yearly training schedule, as discussed in the next sections. Recruiters then recruit soldiers to attend a specific ARTC in accordance with the schedule.

C. ARMY RECRUITMENT TRAINING CENTRE

ARTC is the initial training location for all soldiers joining the Australian Army. It is where soldiers of all trades are taught basic military skills and knowledge. While at ARTC, the basic skills are taught to everyone, so a recruit's future role, or ECN, is not relevant. As a result, each ARTC intake has a wide array of recruits with different ECNs.

There are 60 ARTC intakes annually, with two courses running simultaneously, and each course running for approximately 84 days (12 weeks). Much of the work is competency driven. Of the ARTC trainees, 40% do not complete all required competencies and do not graduate within the 12 weeks, and are instead back classed² (LTCOL C. Ibbott, personal communication, March 10, 2015). Recruits generally complete all competencies within a further two weeks, with 15% taking longer than 16 weeks (LTCOL C. Ibbott, personal communication, March 10, 2015).

D. INITIAL EMPLOYMENT TRAINING

ARTC graduates attend ECN-specific IETs, which run for different lengths of time, depending on job specifications. IET courses are run in many locations in Australia, depending on ECN. IETs cover the specific job-related training a recruit needs for his or her recruited ECN. In some instances, multiple ECNs share the same first IET course requirement. For example, most tradesmen (e.g., electricians, carpenters, plumbers) are

² The term "back class" means to be held back and not graduate at the originally scheduled time. This occurs because the recruit has failed to complete the required competencies, often due to illness or injury.

required to complete the first Engineers IET course prior to completing individual specialized training.

There are several categories of IET requirements, each depending on the specific ECN's requirements. For some ECNs, only one IET course is required to be completed. However, other ECNs require many IET courses, often in a certain order, and others have prerequisite courses that must be completed before the recruit is paneled³ on his or her IET courses. This thesis only considers the first course required following ARTC, regardless of how many following courses the recruit may require. Finally, there are five ECNs that fall under flexible recruitment, meaning recruits may begin their IET at any time, as it is a training requirement to be completed individually. For example, musicians (ECN 240), have flexible IETs; as once they complete ARTC, they begin their individual training on an instrument.

E. SCHEDULING PROCESS

The planning tool used currently for coordinating ARTC and IET courses is called the Soldier Training and Induction Generator (STIG). The STIG identifies which ECNs require recruitment, and when they should be recruited. This generator aims to achieve certain ECN targets and to ensure all ARTC and IET courses are filled. The STIG involves a manual process of allocating each position on an ARTC course with an ECN. This manual process takes several weeks to complete and is affected by human error, which often results in huge delays between courses.

In some cases, IET courses begin two days before an ARTC graduation and in other cases, trainees have a four-month wait for IETs following ARTC (LTCOL C. Ibbott, personal communication, March 10, 2015). This training inefficiency creates a resource loss, both in time and money, for the Australian Army.

The Army recently instituted a zero-risk requirement for scheduling of recruits' training, outlined in the Army Workforce Supply and Management Group's (AWSMG) procedures manual (Khan, 2014). This policy requires that every recruit with a position

³ The term "paneled" means to have a trainee's name placed on a course attendee list.

on an ARTC must have a guaranteed spot on an IET course. This policy does not, in most cases, take into account attrition rates of recruits who drop out of ARTC before graduation and therefore never fill their corresponding IET positions.

IET gaps made by the ARTC dropouts are often used for trade transfers, which occur when a soldier transfers ECNs. Transfers can be lateral, when the recruit transfers from another branch of the military, or can occur because the recruit was back classed in either an ARTC or IET course. Trade transfers, lateral transfers, and back classes are beyond the scope of this thesis.

III. LITERATURE REVIEW

This chapter reviews the most relevant and recent studies that present a schedule modelling approach similar to the one in this thesis. The review of previous work provides this thesis with a framework that helps outline its modelling and analysis approach.

A. DETAR'S THESIS

Detar (2004) aimed to reduce the time lost per year from non-infantry U.S. Marines awaiting entry-level training for their Military Occupational Specialty (MOS) schools following Marine Combat Training (MCT). Detar's research question was significantly similar to the problem being analyzed in this thesis. His work focused on reducing the U.S. Marine Corps' weeks lost awaiting training, while this thesis model aims to reduce the days lost to the Australian Army between courses.

Detar's 2004 thesis employed an integer linear program using the General Algebraic Modelling System to create a model designed to develop an optimal schedule for all non-infantry MOS initial courses. Its model also used past recruitment statistics to predict how many recruits of each MOS are available at any given week, taking into consideration attrition variables for each MOS. This thesis also uses integer linear programming; however, it uses the Analytic Solver Platform to create the model in order to establish an optimal allocation of all ARTC and IET recruits. This model also uses fixed dates for all ARTC and IET courses and fixed recruitment figures for the year, and assumes no attrition occurs, focusing instead on optimizing the allocation of personnel to courses to reduce wait times.

1. Assumptions

Detar's 2004 model assumes all of the previous year's students were paneled on the final MOS course of that year, and therefore, none are left waiting for training in the next year. This thesis applies a similar concept on Model 1, which assumes there are no students from the previous FY awaiting IET courses. Model 2, however, acknowledges

that the graduates of the final ARTC in the previous FY must attend an IET in the current FY. As such, Model 2 assumes that all IET courses before the end of the first ARTC of the year (26 Sep 16) are filled by students from the previous FY ARTCs. This essentially allows the model to schedule a full FY for ARTC panels—from 27 Sep 16 to 26 Sep 17—for IET allocation.

Detar also assumes that Marines can begin their MOS training the week following MCT graduation. In this thesis, however, the objective is to maintain a 14 to 28 day gap between the two courses to allow for travel, relocation, back classing at ARTC, and other variables.

Neither Detar's 2004 model nor the model developed in this thesis examine subsequent courses following the initial MOS or IET course, although in both cases there is a high possibility that there are follow-on courses in the soldiers' training continuums. Both Detar's work and this thesis do not factor in alternate means of entry to MOS/ IET courses, such as trade transfer, lateral transfers or Reserves, as these entries occur irregularly.

2. Penalties

Detar's 2004 model applies penalties to discourage long wait times between MCT and MOS training, with penalties in Marine weeks. His model uses heavy penalties to discourage "undesirable" outcomes, but allows looser constraints when appropriate. For example, he uses a discounted penalty so that courses earlier in the year are more heavily penalized for having long wait times, whilst applies less penalty later in the year. This encourages enforcement of the schedule earlier in the year and allows some flexibility later in the year.

This thesis draws from Detar's (2004) penalty applications, using penalties to discourage any wait time of less than 14 days or more than 28 days between ARTC and IET. The objective function for the model is to minimize the cumulative penalty rate. Very large penalties are similarly used in this thesis to discourage the model from allowing IET courses to be scheduled before ARTC courses.

3. Findings

Detar (2004) found that some MOSs shared a common first course in their training continuums. To manage this, he summed those MOSs together to ensure that the MOS course attendance fell between the course minimum and maximum panel sizes. This thesis applies a similar principle when multiple ECNs are required to attend the same first course in their IET sequences.

Detar (2004) also found several course capacity inconsistencies, where there were more Marines of one MOS than there were available training slots that year. He solved this by increasing the number of course offerings. This thesis also finds the Australian Army has IET course capacity inconsistencies, yet instead of increasing the courses offered (as they are fixed), the author established a dummy variable for each ECN titled “Course Number FY 17–18,” which is where any excess soldiers were placed for IET training in FY17/18. There are more soldiers allocated to these dummy variables in Model 1 than in Model 2, where there are more IET course offerings available for allocation.

In summary, Detar (2004) provided a model designed to reduce the wait time between entry-level courses for the U.S Marine Corps. The use of penalty rates to discourage long wait times is particularly important for this thesis, as is the use of integer linear programming to solve the problem. Detar’s findings regarding course capacities inconsistencies and joint MOS courses are also particularly pertinent to this thesis.

B. APTE, APTE AND VENUGOPAL’S JOURNAL ARTICLE

Apte, Apte and Venugopal (2007) attempted to identify an optimal schedule that minimizes the costs associated with reducing the allocated wait time for a service person (e.g., an electrician) to complete non-emergency works. This thesis is similar in its aim to identify an optimal schedule that minimizes the course wait time for students in days between courses (with a goal of reducing this time to 14–28 days).

Apte et al. (2007) identified the cost differential between meeting a client’s preferred timeframe and achieving the work in an alternative promised time frame. The authors used a two-cost penalty rate, one for costs to the business and one for costs to the

client, trying to minimize the overall cost. The client's penalty rate is based on how much the client values his or her time (for example for one hour lost, the customer could have been paid \$50/hour in their job; hence, one hour lost equates to a \$50 penalty). The penalties used in this thesis are more similar to Apte et al.'s rate than to Detar's (2004), which are discounted over time. The major penalty difference between the Apte et al. model and the one used in this thesis is that Apte et al.'s penalty rate is a fluctuating figure based on each person's value of their time, making the results easily skewed. Instead, this thesis applies a standard penalty for every day the training gap between ARTC and IET is over or under 14–28 days, with the objective to minimize the penalties applied.

Apte et al. (2007) solve this scheduling problem using a “time-oriented nearest-neighbor heuristic.” This uses scheduling to build an optimal route for each field service tradesman to complete in a day so that all customers are scheduled as close as possible to their preferred time. The scheduling tool focuses on geographic location and preferred service times. This thesis uses a similar scheduling tool concept, not in the sense of distance, but rather in the time between courses; trying to put together the optimal route for students to take from ARTC to their IET. Apte et al. aimed to minimize the total cost to the company and the client, while this thesis aims to reduce the number of lost days between courses.

Overall, Apte et al. (2007) provides a good example of a scheduling problem and model, but confirms the need to ensure that the penalty rates used in this thesis are set.

C. ARMY WORKFORCE SUPPLY MANAGEMENT (AWSMG) PROCEDURES MANUAL

The Australian Army's scheduling process was formalized on November 19, 2014, (Khan, 2014) in the development of the AWSMG procedures manual, yet not fully implemented until July 2015 (MAJ M. Lewis, personal communication, Nov 11, 2015). This manual outlines the entire process of joining the military for officers and soldiers. It also outlines the scheduling requirements, processes and planning that go into the training continuum. At the time this thesis was written, the manual had only effectively been in action for six months, and therefore, its results were not yet quantifiable. Prior to this

manual, there was no formalized training allocation process, causing significant issues, backlogs and congestion at training commands.

The AWSMG manual specifically outlines avenues and processes involved for entry into the Army. It also covers each agency's responsibilities for the modelling and planning of the training continuum for ARTC through to IETs. The manual specifies that "all gaps between courses ... are to be 2–3 weeks wherever possible" (Kahn, 2014, p. 14). The creation of this manual was the catalyst for this thesis. A model needed to be created to demonstrate the effectiveness and achievability of the training gap between ARTC and IETs. This thesis, however, used a slightly longer 2–4-week training gap to allow some flexibility in the model.

The manual also outlines that wait times of more than 56 days are to be reported, requiring approval from higher authorities. As a result, this thesis not only reports on how many trainees have 2–4-week gaps between training, but also how many of the trainees have over a 56-day wait time, requiring approval. This thesis identifies these large training gaps so that, in the future, they can be used as grounds to change course dates.

The zero-risk requirement, as discussed in Chapter II, can be found in the AWSMG manual. This policy requires every ARTC trainee to have a guaranteed follow-on IET position identified. The manual outlines one exception to this rule; when there are more trainees than IET positions available in a specific ECN, meaning the recruitment figures are above the IET training capacity due to the trade's high ECN attrition rate at ARTC (e.g., ECN 343 Riflemen) (Khan, 2014). This thesis links every ARTC trainee with an IET position if there is a position available. Those trades that have more trainees than IET positions are outlined in the results, as these could become liabilities or congestion points if the attrition rate varies in a given year.

The AWSMG manual also outlines that any training gaps made by attrition from ARTC before IETs can be filled by alternate entry methods (e.g., lateral transfers, trade transfers or Reservists) . These positions are filled on an as-needed basis. This thesis does not consider any alternate entry methods to the ARTC to IET training cycle.

Overall, the AWSMG manual outlines the current formalized initial training scheduling processes and procedures used in the Australian Army. It is particularly relevant to this thesis because the model developed, if accepted by the Australian Army, will be included in future modifications of this manual.

IV. ANALYSIS

A. METHODOLOGY

This thesis uses linear programming to develop a model for scheduling the training sequence for the Australian Army in FY16/17. This section describes the typical components of a linear program to facilitate the presentation of the model.

A linear program (LP) model is a mathematical model used to identify an optimal solution to a limited resource allocation problem. It has three major components:

- decision variables
- objective function
- constraints

Decision variables are what the model is solving for, or what it wants to find (Balakrishnan, Render, & Stair, 2013). A decision variable is generally titled as x_i and further variables labelled x_j , x_k , x_l etc., as required. In this thesis, decision variables are the number of recruits to be entered into each combination of ARTC and IET courses.

The objective function is the program's aim—to either maximize or minimize something (e.g., maximize revenue, or minimize cost) (Balakrishnan et al., 2013). This thesis aims to minimize the penalties applied to the training gap between ARTC and IET.

Constraints are the limitations put on the model (Balakrishnan et al., 2013). In this thesis, for example, course maximum panels are a limitation. Another set of constraints used in this thesis' model are penalty rates—a set mathematical value to be applied to decision variable values. In this model, penalty rates ensure the model achieves a 14 to 28 day gap between ARTC and IET. Penalties are also used to strongly discourage the model from attempting to schedule an IET before an ARTC.⁴

⁴ For more details on linear programming, refer to Balakrishnan et al. (2013).

B. DATA

The data used for this thesis was provided by the Australian Army Directorate of Workforce Modelling, Forecasting and Analysis and the Directorate Workforce Management–Army.

C. ASSUMPTIONS

The following assumptions were made prior to the development of this model:

- The recruiting cell in the Australian Army can recruit exactly the correct number of ECNs for each ARTC and therefore can accurately achieve the FY16/17 target figures.
- There is no attrition from recruiting, ARTC or the first IET course.
- Course panels' minimum and maximums for FY16/17 will be the same for FY17/18.
- All decision variables are assumed to be positive and continuous, with no constraints requiring integer solutions. Due to the LP model's formulation, only whole integer answers are found; however, this is not a constraint.

D. MATHEMATICAL MODEL

The model is defined mathematically in two formats, first using basic terminology, then in canonical formulation.

(1) Decision Variables

There are 4,410 variables, which are a product of 30 ARTC courses by 147 IET courses (broken down into 117 IET courses in FY16/17, 5 IET courses with flexible dates and 25 IET courses in FY17/18), where:

x_{ijk} = The number of soldiers to attend ARTC course i for IET course j session number k

a_i = end date of ARTC course i

b_{jk} = start date for IET course j , session k

Δ_{ijk} = training difference = $b_{jk} - a_i$

(2) Objective Function

Minimize the training gap between ARTC and IET, through the use of a penalty system, to between 14 and 28 days for all ECN.

$$\text{Min } \sum x_{ijk} (\text{penalty})$$

(3) Penalty

A penalty was used to penalize options where the training gap fell outside the 14–28 day difference.

$$\text{If } 14 \leq \Delta_{ijk} \leq 28, \text{ penalty} = 0$$

$$\text{If } \Delta_{ijk} < 14, \text{ penalty} = 14 - \Delta_{ijk}$$

$$\text{If } \Delta_{ijk} > 28, \text{ penalty} = \Delta_{ijk} - 28$$

(4) Constraints

There are a total of 202 constraints, broken down to 30 ARTC maximum panel constraints, 147 IET maximum panel constraints and 25 ECN target constraints.

ARTC Maximum Panel Size

Each ARTC course has a maximum panel of 55; however, as 2 ARTC courses are run concurrently, the maximum panel is actually 110 for the two courses together (e.g., ARTC 0688&0689 has a maximum panel (upper bound) of 110).

$$\text{ARTC Upper Bound} - \sum x_i \leq 110$$

IET Maximum Panel Size

Each IET course has a maximum number of students it can accept per course.

$$\text{IET Upper Bound} - \sum x_{jk} \leq \text{maximum panel for course } j \text{ session number } k$$

Yearly Target of Recruits for Each ECN

This target is taken from the recruiting targets for FY16/17. The sum of all recruits attending j IET courses must equal the target number of recruits for that ECN (or group of ECNs).

$$ECN \text{ target} - \sum x_j = \text{target no. recruits for ECN}$$

Canonical Formulation of Model

Let

x_{ijk} = number of soldiers to attend ARTC course i for IET course j, session k

a_i = end date for ARTC course i

b_{jk} = start date for IET course j, session k

Δ_{ijk} = training difference = $b_{jk} - a_i$

r_i = ARTC course i, maximum panel size (110 people)

u_{jk} = IET course j, session k maximum panel size

z_j = target number of recruits for each ECN, all of whom must attend IET course j

$\forall$ = for all.

Then the problem can be stated formally as

$$\text{Min } \sum_{ijk} x_{ijk} \{ (14 - \Delta_{ijk})^+ + (\Delta_{ijk} - 28)^+ \}$$

Subject to

$$\sum_{j,k} x_{ijk} \leq r_i \forall i$$

$$\sum_i x_{ijk} \leq u_{jk} \forall j, k$$

$$\sum_{i,k} x_{ijk} \leq z_j \forall j$$

E. MODEL DEVELOPMENT

During the development of the model, two problems were identified. Remaining within the FY16/17 timeframe led to

1. None of the end of FY ARTC trainees were allocated to an IET course within that FY as there were no IET courses available until the next FY.
2. None of the early IET courses were filled, as the first ARTC course offered within the FY did not finish until 26 Sep 16. These early IET courses are likely filled by ARTC trainees from the previous FY.

The problems were overcome by developing two model extensions:

Model 1: Included all ARTC and IET courses for FY16/17, but also included a dummy FY17/18 IET course for each ECN, designed to capture any ARTC trainee who had to complete IETs in the next FY. For example, if there were not enough positions in the current FY IET courses, remaining trainees would be allocated to this dummy FY17/18 course. This model rectified the first problem.

Model 2: Like the first model, this model included a dummy FY17/18 IET course for each ECN. It also made the following assumption: all IET courses scheduled in FY16/17 which begin prior to the completion of the first ARTC course of the FY would be offered again at the same time in the next FY. As a result, any IET course beginning on or before 26 Sep 16 (the completion date of the first ARTC for the FY) was modified to be offered 365 days later. This model solves the first and second problems identified previously. The concern with this model is it relies on assumed dates, which may lead to some issues if dates change significantly.

F. COURSE REQUIREMENTS

Another issue identified in the development of the model was that multiple ECNs had the same first IET course requirement. This required the model to identify which ECN was more important to place on an IET course, which is outside the scope of the models' development. In order to rectify this, any ECNs with the same initial IET course requirement were listed as a group ECN, with the total target a sum of each ECN's

specific recruitment targets. This allows the model to provide an optimal solution for course attendees, leaving the allocation per ECN up to the relevant decision makers.

As an example, ECN 296 and ECN 401 are both required to take the course IET QM SPEC BASIC, hence they were listed as ECN 296/401 with a total recruitment target of 212 (ECN 296's target of 182 soldiers plus ECN 401's target of 30 soldiers).

There are five ECNs (ECN 146, 229, 240, 418 and 421) for which the Australian Army conducts a flexible recruitment process, meaning these recruits have no specified IET dates. As a result, the model managed these recruits so that, no matter which ARTC course they attended, they would have 14–28 days before their IETs.

G. PANEL SIZES

ARTC and IET panel size maximums were strictly enforced in both models due to the impacts of exceeding those maximums. These impacts would include not being able to maintain the Australian Army required student-to-instructor ratios and not having enough accommodation, resources, capacity, funding etc., for the students.

Panel minimums were not enforced, as doing so constrained the model too much; as there was not a sufficient number of students to achieve all course minimums. This is an intended feature of the model, as it allows planners to identify course gaps and vacancies ahead of time. This allows them to pre-plan for those courses and either fill those vacancies with trainees not included in the model (such as reserves, lateral transfers, service transfers, etc.) or reduce the staffing requirements for those courses. In Model 1 all course minimums were achieved and in Model 2 all course minimums were achieved except for two ECNs.

V. RESULTS

This chapter outlines the findings of the two models developed in this thesis and explains how they are applicable to the Australian Army.

A. RECRUITMENT TARGETS

Before either model was run, the following ECNs were identified as having a higher recruitment target than their relevant IETs could train in any given year, regardless of when ARTC was attended:

- **ECN 298**—had a recruitment target of 74 but could only train 72 personnel (3 courses x 24 max panel) within the year.
- **ECN 079/343**—had a recruitment target of 1,115, but could only train 1,056 (22 courses x 48 max panel) within the year.
- **ECN 099/162/165/171/218/237/250/254/255/274**—had a recruitment target of 532 but could only train 360 (12 courses x 30 max panel) within the year.

While it is understood a small percentage of additional numbers might be recruited to cover trainee losses at ARTC, in some ECNs the recruitment target was so great that it may have a detrimental impact on the average delay between ARTC and IET, particularly in the long term. All excess recruits from ECNs in this category were placed into the dummy FY17/18 IET course for their specific ECN, regardless of which model was used.

B. MODEL 1 RESULTS

Model 1 allocated all 3,086 recruits to ARTCs within the FY. Of all trainees, 65% were placed in IETs within FY16/17. Those remaining, 1,067 trainees, as shown in Table 1, were placed into the FY17/18 dummy IET courses as a result of a lack of course positions available in the FY16/17. This was due to IET courses beginning prior to the first ARTC course completion in the FY.

Table 1. ECNs with a Higher Recruitment Target than Can Be Trained in FY16/17 under Model 1

ECN	Recruitment target positions greater than IET trainee positions
ECN 029	6
ECN 084	11
ECN 298	2
ECN 315	10
ECN 345	5
ECN 063/064/065	99
ECN 079/343	395
ECN 099 / 162 / 165 / 171 / 218 / 237 / 250 / 254 / 255 / 274	382
ECN 153 /154/411 / 412	43
ECN 296/401	68
ECN 661 / 662 / 663 / 665	46
TOTAL	1,067

All IET courses that were allocated trainees remained within their specified minimum and maximum panel constraints. There were 57 IET courses with 0 trainees allocated, many of which fell before the conclusion of the first ARTC course in the FY. The IET course allocation developed in Model 1 is outlined in Table 2.

Table 2. IET Course Allocation from Model 1

Time frame between ARTC and IET	Number of attended courses that fall within that time frame	Average number of days between ARTC and IET if it falls within that time frame
Under 14 days	10 courses	8 days
Between 14 and 28 days	30 courses	19 days
Over 28 days	31 courses	75 days
Over 56 days	23 courses	87 days

*** Table does not include 1,067 trainees pushed into dummy FY17/18 courses, as dates for those courses are unknown.

*** Table does not include those who are recruited under flexible recruitment.

The large gap between courses over 28 days is due to the deficiency in trainee positions between 26 Sep 16 and 30 Jun 17. Therefore, the model forces trainees into large wait times just to fill courses, rather than leaving them for the next FY. Figures 2, 3, 4 and 5 demonstrate the key results of Model 1.

Figure 2. Model 1 ARTC Course Attendance

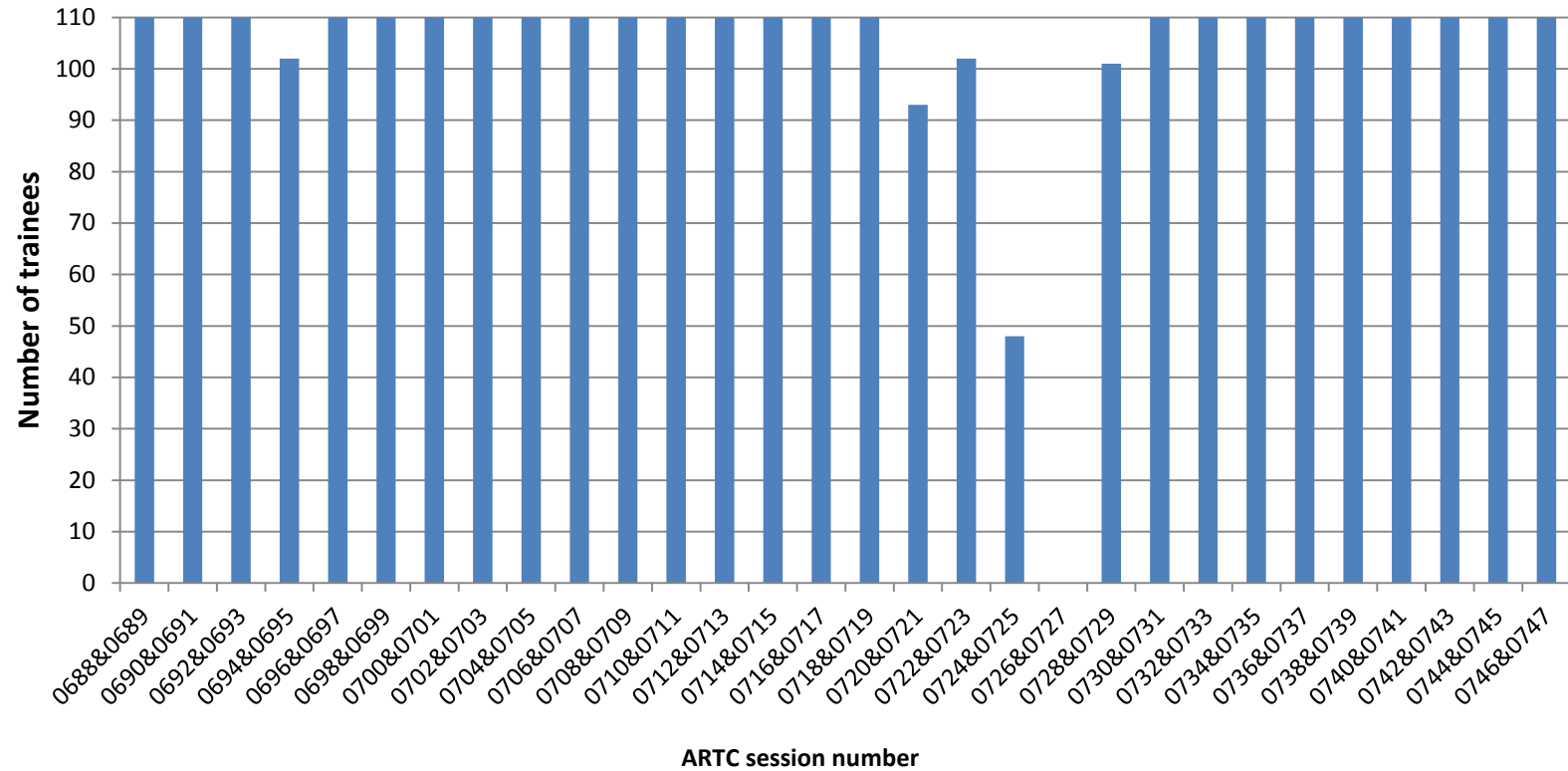


Figure 3. Model 1 IET Position Backlog Required for FY17/18—Total 1,067 Recruits

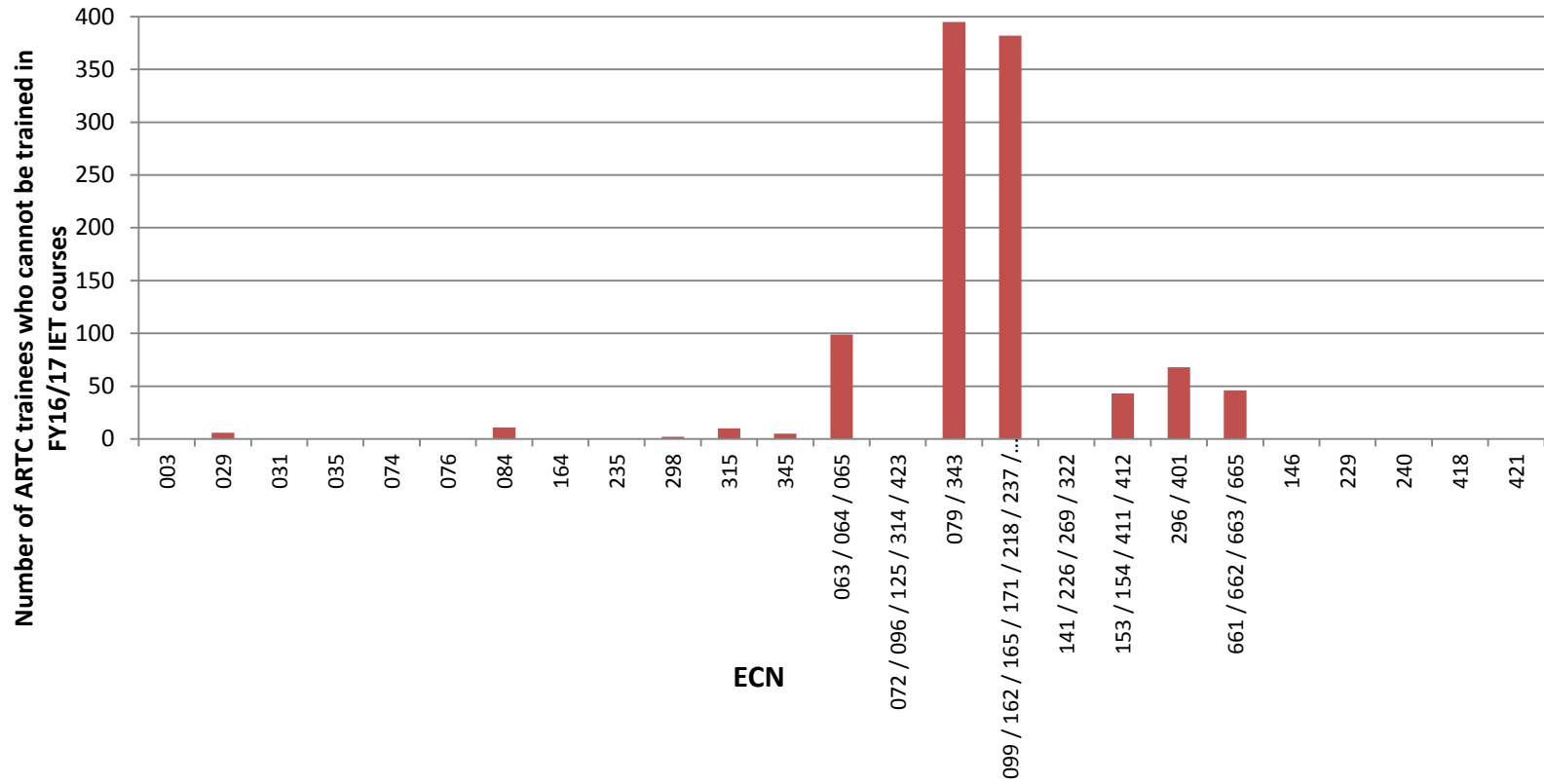


Figure 4. Model 1 Total IET Positions versus Target Number of Positions

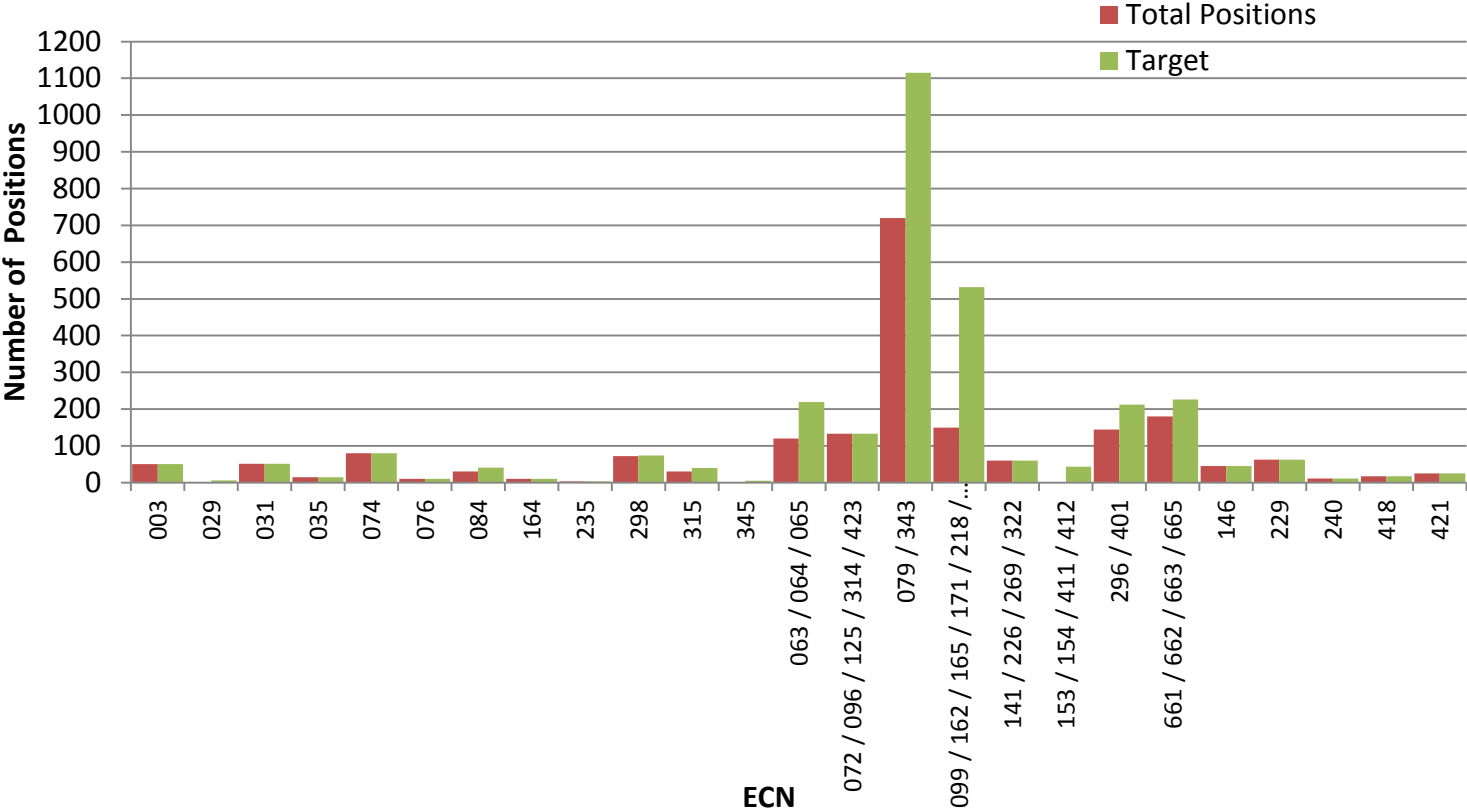
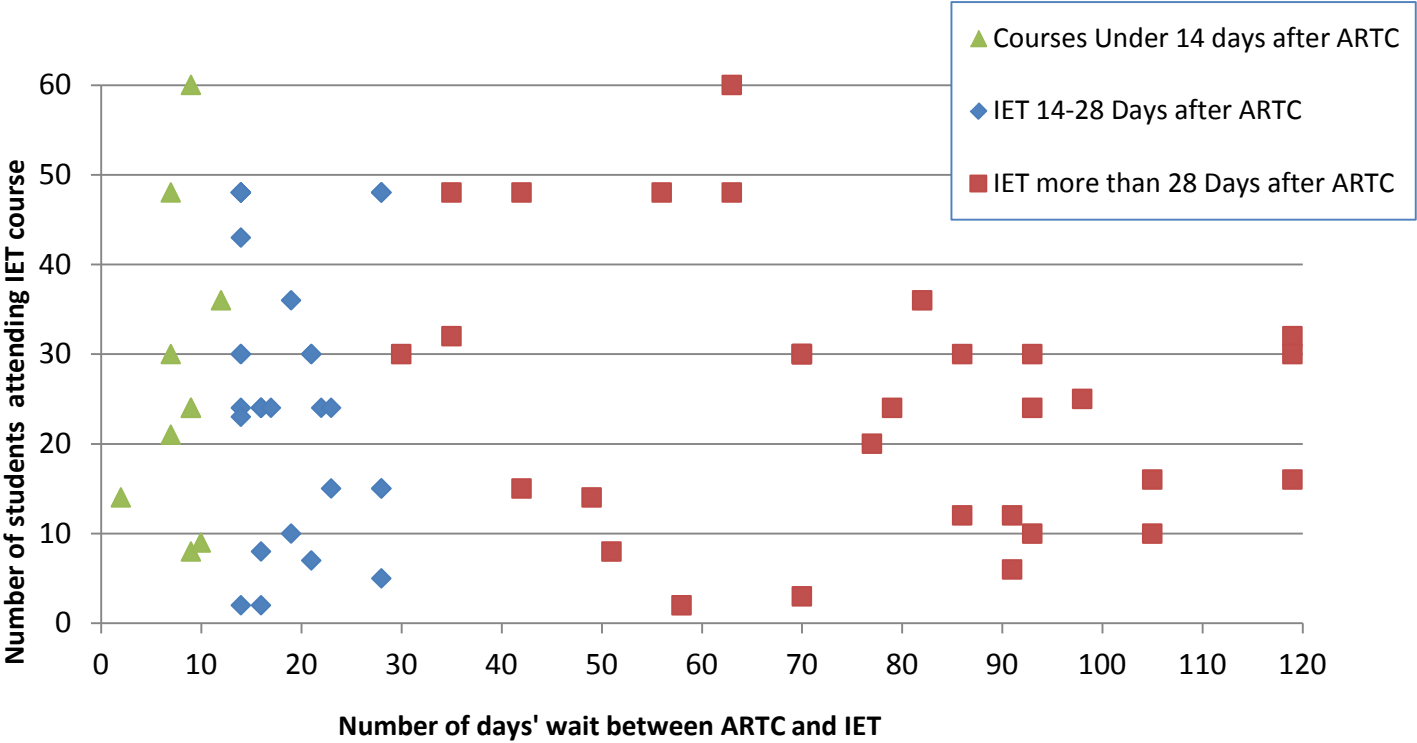


Figure 5. Model 1 Number of Students Attending IET versus Days' Wait between IET and ARTC



*** Does not include 1,067 recruits placed in the dummy FY17/18 IET courses or the recruits that have flexible recruitment

C. MODEL 2 RESULTS

Model 2 makes the following assumption: all IET courses scheduled in FY16/17 which begin prior to the completion of the first ARTC course of the FY would be offered again at the same time in the next FY. As a result, any IET course beginning on or before 26 Sep 16 (the completion date of the first ARTC for the FY) was modified to be offered 365 days later.

Model 2 allocated all 3,086 recruits to ARTC cohorts within the FY. Of all recruits, 92% were placed in IETs between the dates 27 Sep 16 and 26 Sep 17. The remaining 233 trainees, as shown in Table 3, were placed into the FY17/18 dummy IET courses due to a lack of course positions available in FY16/17. The only ECNs in FY16/17 under Model 2 that had to place recruits into the dummy IET course were the three identified as having more positions demanded than IET position offerings within that FY.

Table 3. ECNs with a Higher Recruitment Target than Can Be Trained in FY16/17 under Model 2

ECN	Recruitment target positions greater than IET trainee positions
ECN 298	2
ECN 079 / 343	59
ECN 099 / 162 / 165 / 171 / 218 / 237 / 250 / 254 / 255 / 274	172
TOTAL	233

Forty-four different IET courses were “assumed” into early FY17/18 (any IET course initially starting on or before 26 Sep 16 was re-offered 365 days later) and 32 of those had trainees allocated into them. The IET course allocation developed in Model 2 is shown in Table 4. Figures 6, 7, 8 and 9 demonstrate the key results of Model 2.

There were 30 IET courses with 0 trainees allocated. All IET courses that were allocated trainees remained within their specified minimum and maximum panel constraints except for two courses:

1. **ECN 164, Course Number 212737, Session Number 0035:** had 2 trainees allocated (where the minimum course panel was 3).
2. **ECN 153/154/411/412, Course Number 213393, Session Number 0035 +365 days:** had 3 trainees allocated (where the minimum course panel was 10). This occurred because the recruitment target was set at 43 and the best ARTC course (based on time between ARTC and IET) was filled to its maximum panel of 40. The remaining IET courses had significantly longer wait times between ARTC and IET, hence only 3 trainees being allocated to it.

Table 4. IET Course Allocation from Model 2

Time frame between ARTC and IET	Number of attended courses that fall within that time frame	Average number of days between ARTC and IET if it falls within that time frame
Under 14 days	9 courses	9 days
Between 14 and 28 days	36 courses	22 days
Over 28 days	60 courses	50 days
Over 56 days	23 courses	78 days

*** Table does not include 233 trainees pushed into dummy FY17/18 courses, as dates for those courses are unknown

*** Table does not include those who are recruited under flexible recruitment.

Figure 6. Model 2 ARTC Course Attendance

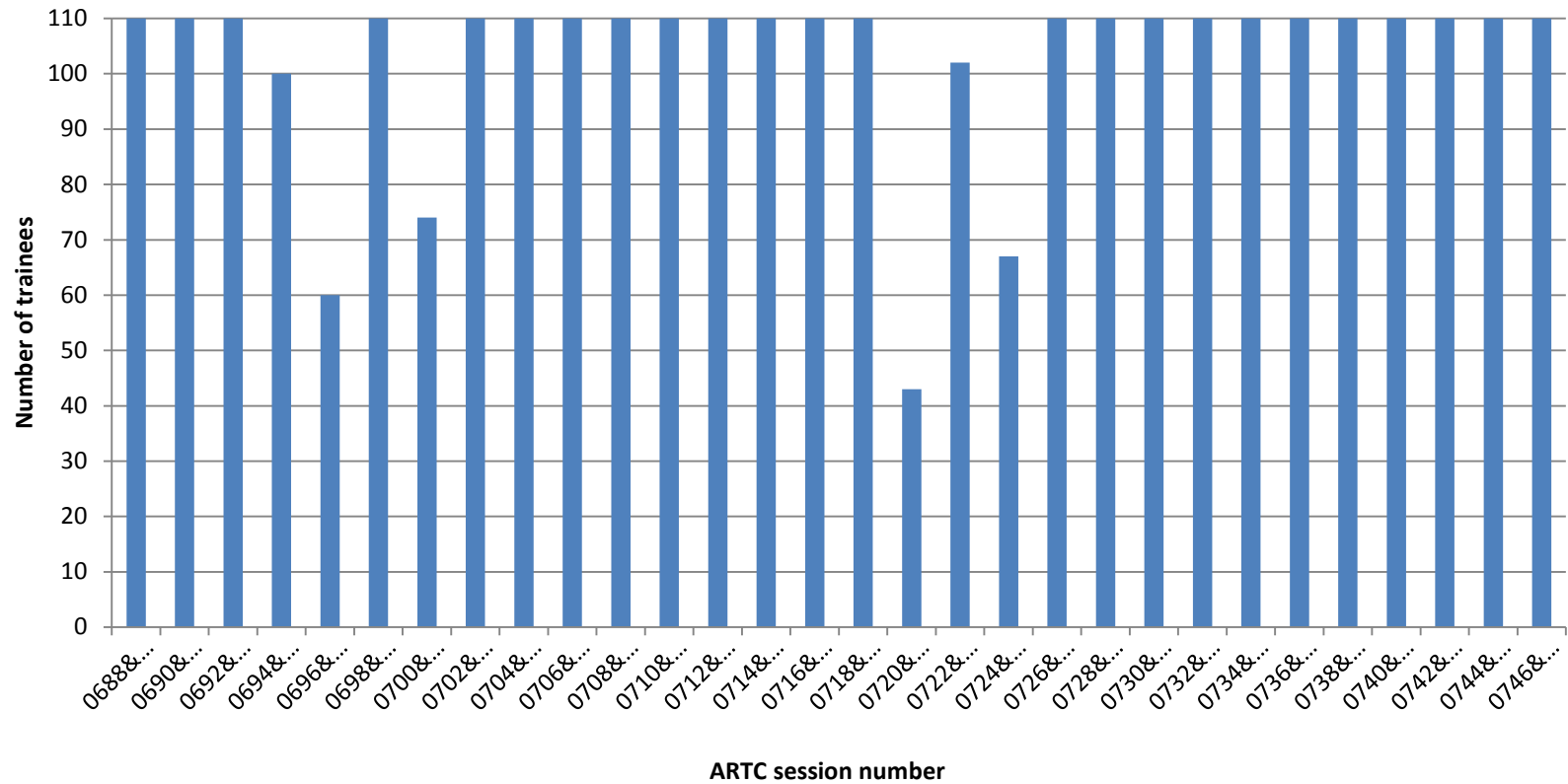


Figure 7. Model 2 IET Position Backlog Required for FY17/18—Total 233 Recruits

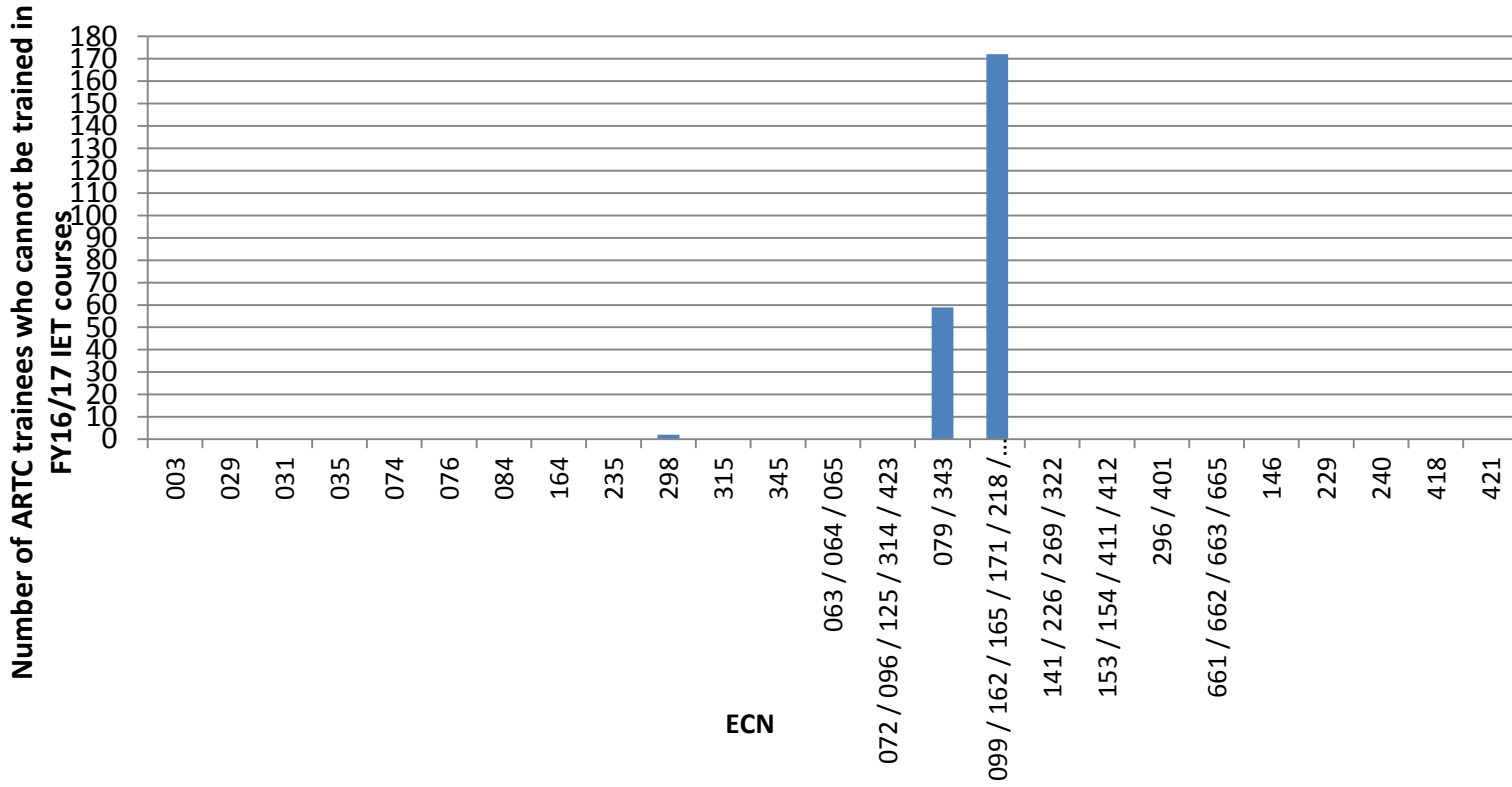


Figure 8. Model 2 Total IET Positions versus Target Number of Positions

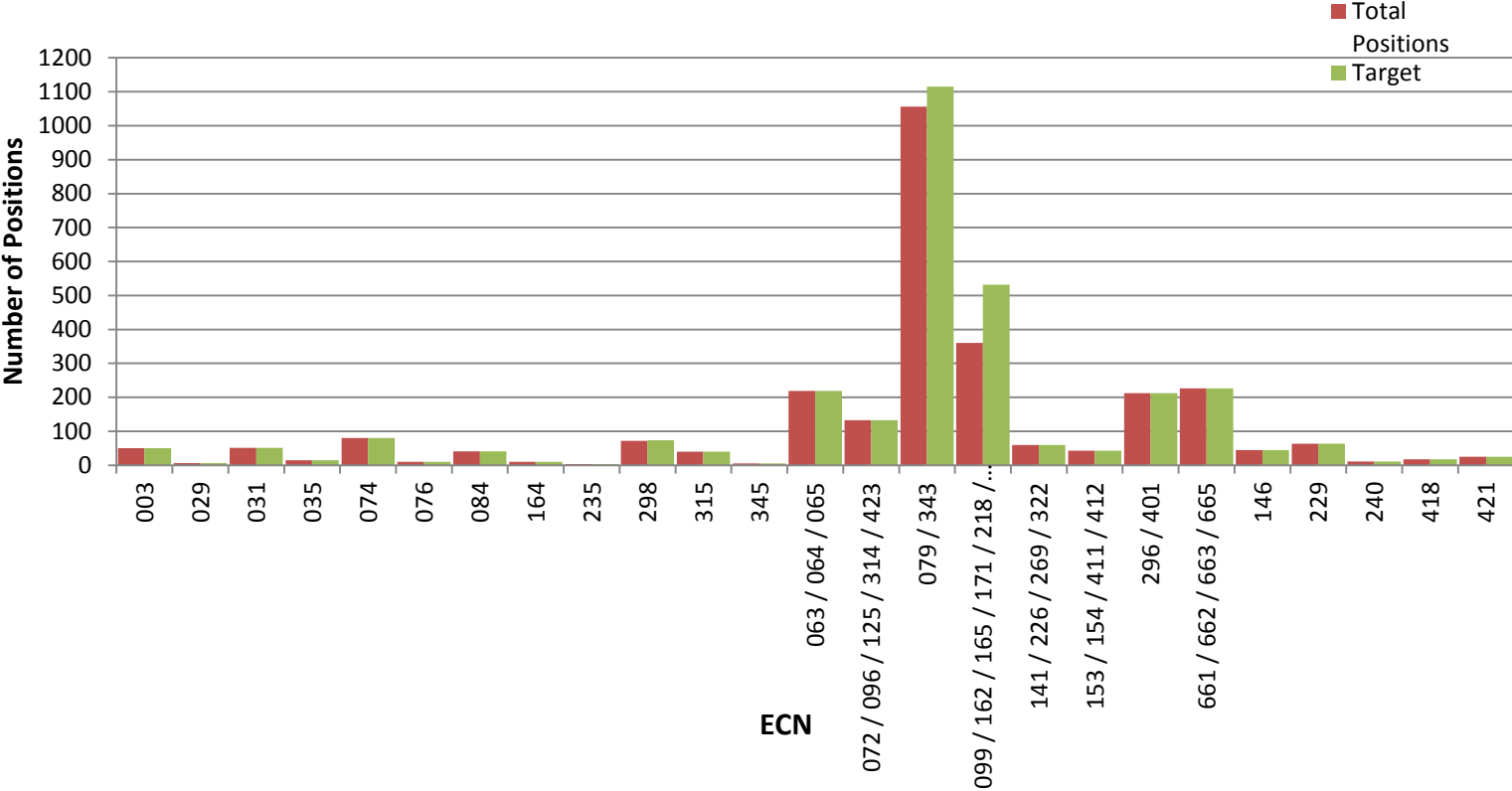
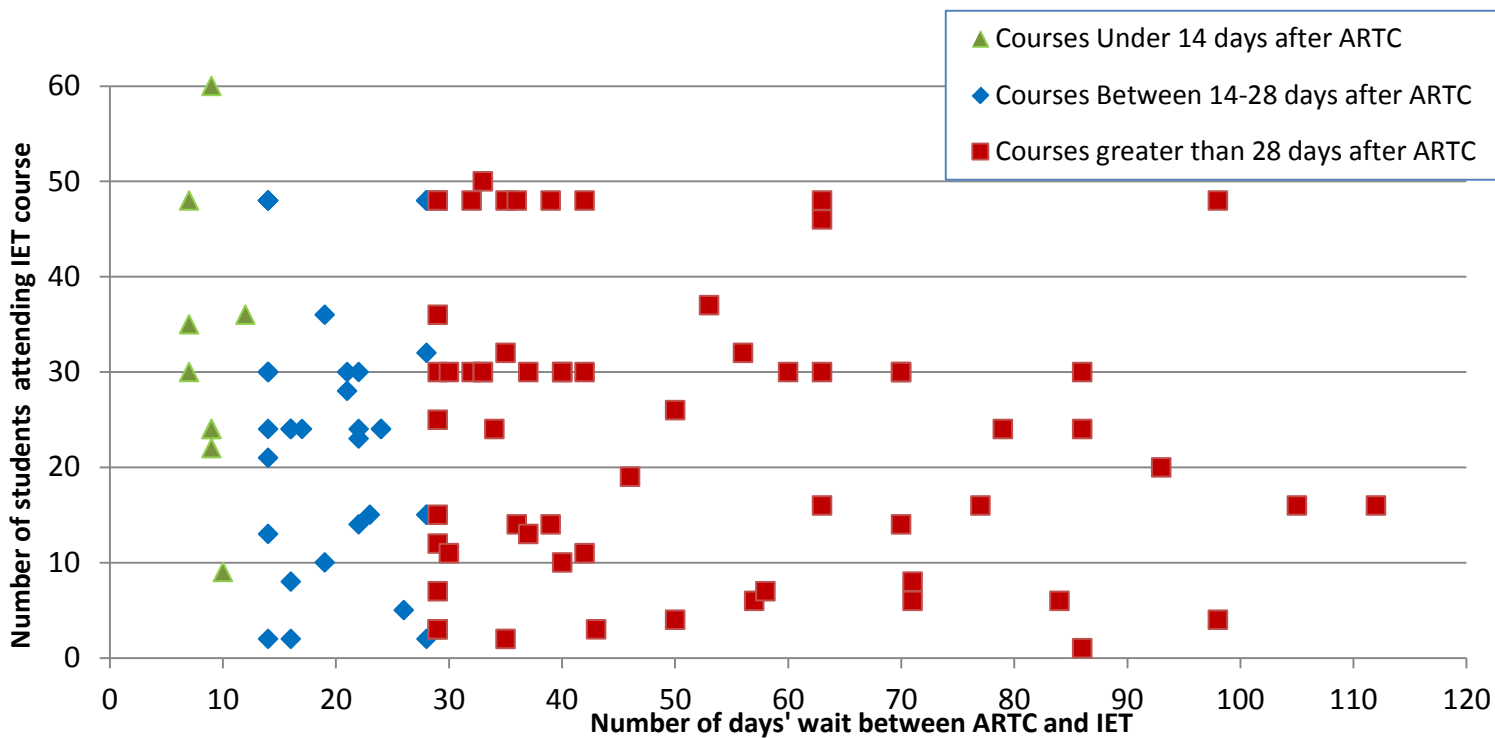


Figure 9. Model 2 Number of Students Attending IET versus Days' Wait between IET and ARTC



*** Does not include 233 recruits placed in the dummy FY17/18 IET courses or the recruits that have flexible recruitment

D. RESULTS COMPARISON

It is difficult to compare the two models due to the different assumptions used in Model 2. Model 1 places a significant number of trainees into dummy FY17/18 IET positions, which are dated 01 Nov 17, as no courses are scheduled that far into the future, while Model 2 places trainees into assumed positions for FY17/18 based on the current year's training program. This makes the average number of days waiting for courses incomparable, as the dummy positions make the statistics invalid.

Instead, the validity of the models can be compared—with Model 1 placing 1,067 trainees into dummy FY17/18 IET positions and Model 2 placing 233 into the dummy IET positions. As such, Model 2 is assessed as the more valid model, providing a more robust and effective schedule.

An attempt was made to compare Model 2 against the Soldier Training and Induction Generator (STIG) model developed for FY15/16, but numerous problems were encountered. The STIG for FY15/16 has a number of data inconsistencies, such as IET courses starting before ARTC completion, courses without start dates, different required preliminary IET courses to FY16/17 and, in several cases, recruits without IETs allocated. These inconsistencies were the reason for developing the models in this thesis.

After attempting to rectify these issues, it was identified that different years could not be compared, as each year had completely different recruiting targets, numbers of courses offered, different course dates, etc. As such, there is no way to compare the model to the previously used STIG except to identify that both Model 1 and Model 2 are far faster at solving the scheduling problem than the hand-solved STIG.

With data input and solving, Model 1 and Model 2 took approximately one day to input, and about one minute to solve, while the STIG takes one person approximately one month to prepare (C. Ibbott, personal communication, 10 Mar 15).

VI. CONCLUSION

A. RESEARCH AREA

This thesis developed an optimization scheduling program to assign recruitment into the Australian Army by Employment Category Number (ECN). This thesis found that it is possible to reduce the wait time between Army Recruit Training Centre (ARTC) and Initial Employment Trainings (IETs) to 14–28 days for some courses, while others were infeasible as course dates were set and did not allow for the required gap. This model will allow the Australian Army to plan annually the optimal recruitment dates to achieve the stated recruitment target for all employment categories.

B. MOTIVATION

Although the models developed in this thesis used FY16/17 data, they will be able to be used for future years' planning purposes. This model will provide a more efficient and adaptable method of recruit allocation to ARTC and IETs than the current manual scheduling process. When implemented, the models developed in this thesis should save the Australian Army time in both the scheduling process and between courses, and should also save money by reducing the wasted man-hours awaiting courses.

C. APPROACH

The models developed in this thesis identify the optimal intake schedules for the year based on the year's required recruitment targets to minimize the time between ARTC and follow-on IETs, optimally to between two and four weeks. The two models developed are both appropriate planning tools, however the second model provides a more accurate and robust solution by including assumed FY17/18 course dates. These assumed course dates could, when future data is available, be confirmed to make the model even more robust.

The models developed provide the Australian Army with a decision support tool calibrated to FY16/17 data which can be adjusted to accommodate changes in data and constraints.

D. RESULTS

Both models are constrained by a lack of future course details (e.g., FY17/18 dates); however, within the limits of the data provided and using the assumption (that courses will be roughly similar between FYs), the models provide the required statistical data to develop a working model for the Australian Army. Model 1 schedules 30 courses within the 14–28 day window while Model 2 schedules 36. With the additional assumption that the IET courses offered prior to the initial ARTC course completion would be offered 365 days later, Model 2 provides an accurate and efficient yearly course allocation model, which is a significant improvement on the manual, month-long process used in the Soldier Training and Induction Generator.

E. RECOMMENDATIONS

From the analysis and results of this thesis, the following recommendations can be made:

1. Model 2 should be implemented for FY16/17, as its results are the most accurate and efficient in the allocation of time (with lower average wait times than Model 1 and a higher allocation of recruits to IETs). Model 2 makes greater assumptions but is more robust and solves the problem of IET courses being undersubscribed early in the FY due to new FY ARTC courses not finishing early enough. It is noted that, at the time of this model's development, dates of courses two years away were unknown; however, the accuracy of this model could be increased by including actual, not assumed, dates for all IET courses offered 27 Sep 16 through 26 Sep 17.
2. For future planning, ARTCs' ECN allocation should be planned FY to FY, while IETs' should be planned 27 Sep to 26 Sep the following year.
3. ECN recruitment targets should only be allocated for those that can be achieved through the yearly IET training cycle. If yearly ECN targets significantly exceed the IET training ability, delays in training may occur within that year and flow on into future FY training continuums. Although

in some cases this may be caused by attrition rates calculated into the target figures, if attrition is lower than expected in a year it may cause significant training delays.

F. FUTURE RESEARCH

Further research on this topic could be conducted by:

- Attempting to incorporate into the model attrition rates from historical data, trade transfers, lateral transfers and back classes to develop a more robust model.
- Identifying courses with significant wait times that could be rescheduled to reduce average wait times between courses.
- Utilizing Detar's 2004 model to identify an optimal timetable for the Australian Army for ARTC and IET course, rather than retaining fixed course dates.

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