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THESIS

REENGINEERING THE UNITED STATES MARINE CORPS' RECRUIT DISTRIBUTION MODEL (RDM)

by

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13. ABSTRACT *(maximum 200 words)*

The United States Marine Corps accomplishes its mission “to put the right Marine in the right place at the right time with the right skills and quality of life” in a variety of ways. One of the information systems assisting the Marine Enlisted Assignments branch is the Recruit Distribution Model (RDM). This thesis proposes changes to the RDM user interface, data management, assignment model, and analysis capability. With the use of business process reengineering, process modeling, mathematical modeling, and database design a fully functional prototype has been developed to address each identified change proposal. This reengineered system includes numerous innovations such as an intuitive navigational scheme using switchboards, and the elimination of manual data entry for data already available in the system. It also provides a number of significant contributions beneficial to the USMC. For instance, the reengineered system allows the user to objectively analyze different results by comparing four different objective measures, and its mathematical model uses commercial-off-the-shelf products eliminating a proprietary solver. All these changes will empower managers to effectively and efficiently manage the assignment of recruits in order to meet the challenges of the 21st century.
REENGINEERING THE UNITED STATES MARINE CORPS’ RECRUIT DISTRIBUTION MODEL (RDM)

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The United States Marine Corps accomplishes its mission “to put the right Marine in the right place at the right time with the right skills and quality of life” in a variety of ways. One of the information systems assisting the Marine Enlisted Assignments branch is the Recruit Distribution Model (RDM). This thesis proposes changes to the RDM user interface, data management, assignment model, and analysis capability. With the use of business process reengineering, process modeling, mathematical modeling, and database design a fully functional prototype has been developed to address each identified change proposal. This reengineered system includes numerous innovations such as an intuitive navigational scheme using switchboards, and the elimination of manual data entry for data already available in the system. It also provides a number of significant contributions beneficial to the USMC. For instance, the reengineered system allows the user to objectively analyze different results by comparing four different objective measures, and its mathematical model uses commercial-off-the-shelf products eliminating a proprietary solver. All these changes will empower managers to effectively and efficiently manage the assignment of recruits in order to meet the challenges of the 21st century.
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I. INTRODUCTION

A. THESIS PURPOSE

The main purpose of this thesis was to reengineer a United States Marine Corps’ Manpower Assignment model concerned with the distribution of recruits to schools. This model is called the Recruit Distribution Model (RDM) [Ref. 1]. Throughout this thesis, the RDM is addressed as either RDM or the old system.

Additionally, an important purpose of this thesis was to build a functional prototype of the reengineered RDM. The new system is called the Recruit Distribution Decision Support System (RDdss). It demonstrates the functionality of the reengineered RDM. Throughout this thesis, the RDdss is addressed as either RDdss or the new system.

The majority of this thesis is devoted to a discussion of the RDdss. As necessary, the RDM is discussed. The following section is a general discussion designed to set the stage for understanding the rest of the thesis. It provides a problem description of recruit distribution in the United States Marine Corps (USMC). The last section of this chapter discusses the significant contributions of this thesis.

B. GENERAL PROBLEM DESCRIPTION

Recruit distribution in the USMC is the process that assigns recruits to an entry level school (ELS) leading to a military occupational specialty (See Figure 1). These assignments are made about 48 times a year, during the last week of Marine Corps Recruit Depot (MCRD) training. In this ending period of the MCRD, the recruits are facing the “Crucible,” which is the final wicket a recruit endures before officially becoming a Marine. Consequently, the use of the titles recruit and Marine are used interchangeably in this paper.

For at least two reasons, this assignment process is a critical manpower function. First, a Marine’s military occupational specialty (MOS) ultimately determines
Figure 1. Assigning Marines to Schools

the member’s career. Therefore, it is in the best interest of both the Marine and the USMC that a school assignment matching the Marine’s desire is made. Second, the success obtained by a service member during his or her time in the USMC is partially based upon successful completion of their ELS, where a pattern of success is established. Therefore, a school assignment maximizing the chances of the Marine completing their training is important. So, fulfilling the Marine’s desire and matching him or her to an MOS (i.e. ELS) that fits their personal characteristics is critical to the overall health of the USMC, making the assignment process a critical manpower function [Ref. 2].

Fulfilling the desire of the Marine is accomplished through the use of a contract guarantee. This is called a program enlisted for (PEF), and is specified during the recruiting process. For instance, a PEF = 19 is the “Tank and Assault Amphibian Option.” There are currently two ELS’s associated with this, “M1A1 Tank Crewman” and “Assault Amphibian Crewman.” So, a Marine who chose the PEF = 19 is a possible candidate for these two schools and no others.

Once the Marine’s school options are known, a Marine-to-school fit is deter-
mined for each of these schools (See Chapter III, Section B for details). This fitness
determination is partly made by looking at each ELS’s minimum eligibility require-
ments, which are call mandatory properties. This term “property” is used as defined
by Webster’s Ninth New Collegiate Dictionary: “a quality or trait belonging and
especially peculiar to an individual or thing.” Examples are Age > 18, Clerical >=
80, and Electrical >= 95. The meaning of the first example is obvious. The other
two are based on test scores from the Armed Services Vocational Aptitude Battery
(ASVAB) test.

In addition to the mandatory properties, most schools also specify desirable
properties. A desired property is the same as a mandatory property, except they
are not prerequisites for attending the school. For example, the Traffic Management
Coordination school desires Marines with a Clerical score of at least 100. So, a desired
property of Clerical >= 100 is specified for this ELS.

By using the information obtained from the PEF, mandatory and desired
properties, a fitness matrix is generated. This shows the fit of every Marine to every
school he or she is eligible for. Since there are about 100 schools and on average 700
Marines considered for every run, this matrix has the potential of 70,000 matches.

However, the matrix size is actually bigger. This is because each of the schools
is broken down by classes. Some ELS’s have a class starting each week, others every
month, and others every quarter. Over a given year, these classes total about 1,800.
Following the practice of the USMC, only the classes over the next 3-4 months are
considered during the assignment process (see Figure 2). Therefore, the fitness matrix
is increased to a potential size of 350,000.

The fact that the school classes start at different times throughout the year
and that the assignment process is only conducted 48 times a year (normally this
occurs on Friday) causes the “3-month look ahead” in the model and has implications
important to the USMC. The concern is school seats which never get filled. Each
seat is prepaid, guaranteeing its availability to the USMC. This means every vacant
Figure 2. Assigning Marines to School Classes

spot is potentially a lost resource to the USMC. Therefore, in addition to the Marine-to-school fitness concern, there is also the concern of filling all available school seats before their report date is passed.

Another concern is the problem of unassigned Marines. There are numerous reasons why they may not get assigned. Maybe the only school class the Marine was eligible for is already full. Or, possibly he or she is not qualified for any of the school’s promised by their PEF. A third possibility is errors in the data provided to the assignment process. Regardless of the cause, it requires identification and corrective action.

Finally, a discussion of the internal and external stakeholders associated with the USMC recruit distribution is given. Internally, there are the USMC and the recruits. Since their concerns were discussed above, they are not given any further consideration. Externally, there is the contractor Decision Support Associates, Inc. (DSAI) who has maintained and upgraded the RDM for over 30 years. They also maintain about eight other major systems for the USMC. For their services, the USMC pays a significant amount of money each year. Additionally, DSAI has proprietary software in some of these systems, which has locked-in the USMC to this
company. Besides the contractor, there is one last significant stakeholder, the American taxpayer. In a time of increasing fiscal constraints and shrinking budgets, it is imperative that wise decisions are made in regards to assigning Marines to ELS’s. The American taxpayers expect nothing less.

C. SIGNIFICANT CONTRIBUTIONS

Four significant contributions beneficial to the USMC have been made in this thesis. A detailed discussion of these is given throughout the next three chapters. Here, we list and summarize the contributions.

- Analysis and articulation of the recruit distribution process - by interviewing USMC and DSAI personnel, reviewing available documentation, and operating the RDM we were able to articulate an understanding of the recruit distribution process using IDEF process modeling. Additional data modeling was articulated in a third normal form relational schema [Ref. 3].

- Development of a mathematical model - by analyzing the assignment process, criteria, and constraints, USMC policies and objectives, a mathematical model for the new system was developed.

- Fully functional prototype - an intuitive and easy to understand new system that seamlessly interfaces with the old system was built. It provides an objective means of comparing assignment results of both systems, and was developed using commercial-off-the-shelf (COTS) software applications.

- Elimination of the proprietary solver and associated contractor lock-in - this was accomplished by replacing the proprietary solver with two COTS applications.
II. REENGINEERING MOTIVATIONS AND PROCESS VIEW

The RDM has a number of limitations which motivated the USMC to reengineer it. We start this chapter by listing and describing each identified limitation. Then, to develop a better understanding of recruit distribution in the USMC, two different process views are examined. The first is concerned with the RDM operating environment, and the second is concerned with the first level of the RDdss IDEF0 model.

A. LIMITATIONS OF OLD SYSTEM

Throughout this reengineering effort, a number of limitations of the old system have become apparent. Many of these limits were recognized earlier, and were part of the USMC's motivation to reengineer the RDM. The following is a list of the identified limitations of the old system.

- Navigation
- Data management
- Assignment procedure
- Transaction processing approach

A description of each limitation is now given.

1. Navigation

Navigating through the RDM is not intuitive. It is neither obvious where one should start or where one should go. Navigation is accomplished by initially selecting an option from one of the main display’s drop down menus. This normally results in a window appearing on the computer’s desktop. Then, by pointing and clicking on the displayed window’s buttons, further navigation is accomplished. After working with the RDM for a number of hours, we were able to navigate through the application
to find and display specific windows. However, after a week or two of not using the system, we had difficulty finding our way around again. In the RDdss, we have created an intuitive navigational scheme using switchboards.

2. Data Management

Data management in the RDM is poor, leading to the introduction of numerous errors. The biggest problem in this regard deals with data entry. The RDM violates the basic rule of never requiring the user to enter data already in the system [Ref. 4]. For example, creating a new school in the RDM requires the user to type data into seven different data fields. Only the course identification number has been automated by a drop down list. In the RDdss, when creating a new school we have reduced the manual data entry to one field.

3. Assignment Procedure

There are at least five limitations associated with the old system's assignment procedure. It

- is encoded into proprietary software,
- examines schools sequentially, rather than globally,
- makes assignments based on school priority rather than weights,
- attempts to maximize fill rather than fit-and-fill, and
- is relatively inflexible.

The solver performing these assignments was designed back in the 1950's, where the major concern was speed and using the minimal amount of memory. It is written in Fortran, and is proprietary code owned by DSAI. It does not search repetitively for an optimal solution by trying to maximize or minimize an objective function. Instead, it maximizes the fill of prioritized school seats. In the RDdss, we use a well know algorithm called CPLEX [Ref. 5]. After conducting around 600 iterations of comparing 344 Marines to 576 school classes, it produces an optimal solution. Its
objective function was written to make the assignment procedure flexible. It allows the RDdss manager to “game” the system by making fit-and-fill trade-offs, until a “good” solution is found.

4. Transaction Processing Approach

Finally, the old system follows a transaction processing approach, vice a decision support approach [Ref. 6]. This is partially due to the inflexibility of the solver. However, another contributor is the extreme difficulty in comparing one run to another. Other than providing a means for manually computing the numerical difference in Marines assigned, the RDM provides little insight or information views for comparing runs. This is because there is no way to objectively compare one run to another. As it is now, if the RDM manager launches the assignment model and everybody is assigned, the result becomes the approved assignments. In the RDdss, we have created an entire process devoted to providing insightful analysis of a given run (See Chapter IV, Section D for details). Its purpose is to support the making of wise assignment decisions.

B. A PROCESS VIEW

To develop a better understanding of recruit distribution in the USMC, two different process views are now examined. The first is concerned with the current operating environment of the old system. The goal is to develop a big picture view of this process. For those interested in further study of the old system, Appendix A contains the RDM business process IDEF0 model.

The second process view examined concerns the first level of the RDdss business process IDEF0 model. The goal is to develop a better understanding of the new system, without going into great detail. This lays a good foundation for the RDdss discussions in the remainder of this thesis. Appendix B contains the entire IDEF0 model of the new system.
1. **Recruit Distribution Model Operating Environment**

Figure 3 graphically depicts the operating environment of the USMC recruit distribution. At the top are the policy makers, who forecast and decide how many recruits and corresponding school seats are needed over the next few years. In addition to this, they determine how many PEF's or school guarantees to make available for a given year. Currently, about 65-70% of the recruits enter the USMC with a guarantee. The recruit and PEF authorizations for the following year are given to the USMC recruiters, and the school seats or quotas determined for the following years is input into the By Name Assignment (BNA) system.

The recruiters use the recruit and PEF authorizations in recruiting from the general public. Once a potential candidate is found they take the ASVAB, if they have not already done so. Based on the results, the recruiter can offer different guarantees. Once the candidate signs a contract with the USMC, their test scores, PEF, and other personal information such as age and height are entered into the Automated Recruit Management System (ARMS).

Both the ARMS and BNA systems utilize large main frame databases. They
serve as central repositories for maintaining data on many aspects dealing with the
USMC. Keeping this information stored in one location ensures everyone is using the
same data, providing consistency for all users. One user is the RDM manager, who
retrieves recruit and school information from these systems for use in the RDM.

Additionally, the RDM receives data from two other sources. The MCRD
instructors provide special assignment inputs. These are personnel identified as having
the talents or abilities well suited for a particular school. The other data comes from
the MCT. They provide the RDM manager with reclassification information. For
instance, a Marine is reclassified if he or she is injured during MCT and is unable to
make the start date of their assigned ELS.

All this recruit and school data is input into the RDM, where it is stored
in the Military Operational Data Store (MODS). The model is then run. Once a
satisfactory set of assignments is obtained, the RDM manager uploads the approved
assignments to the ARMS and BNA systems. From this assignment information, the
MCRD generates orders for the Marines graduating from the MCRD.

2. New System Level 0 Diagram

Focus is now shifted to the examination of the first process level of the RDDss.
Looking any deeper will provide more detail than is necessary at this point. As
mentioned earlier, the intent is to lay the foundation for the RDDss discussions in the
remainder of this thesis.

Figure 4 shows the level 0, or context diagram of the RDDss. The program
used to generate this illustration was BPWin, which is based on IDEF0 modeling.
Consequently, all arrows entering from the left are considered "inputs," arrows enter-
ing from the top are "controls," arrows exiting to the right are "outputs," and arrows
entering from the bottom are "mechanisms." A convenient acronym for this is ICOM
[Ref. 7].

- I = Input: something consumed in the process
- C = Control: a constraint on the operation of the process
Figure 4. RDdss Process, Level 0 Diagram

- O = Output: something resulting from the process
- M = Mechanism: something used to perform the process, but is not itself consumed

There are three inputs to the RDdss, the BNA extract, the RD1 file, and the special assignments/reclassifications. The first of these contains a set of school class quotas covering a 120 day period. This comes to the RDdss manager as a fixed-width delimited text file. The RD1 file contains the data for the recruits soon to graduate from the MCRD. It also is a fixed-width delimited text file. The special assignments and reclassifications are the recruits identified with special abilities or talents and the Marines requiring reassignment to a different school class, respectively. This last data comes to the RDdss manager as a memo and not a text file.

The only control is the database (or Military Operational Data Store) used to store the data for the RDdss. Among other things, the MODS contains the informa-
tion specifying the eligibility requirements for each of the schools. This is why it is considered a control. It contains the data controlling or constraining the assignment of Marines to schools.

Besides the approved assignments that were mentioned earlier, the output consists of graphs, reports, and query results. Each graph was designed to provide insight into the current assignment result, plus provide a means for comparing different runs. The reports provide a print-out of information the RDdss manager might find useful. For instance, an approved assignment report and an unassigned Marine report are both available. The query results provide different views of the data in the MODS. For instance, one of the queries provides a listing of the fitness scores of all schools a Marine is eligible for.

Finally, the two mechanisms of the RDdss are the RDdss manager and the commercial-off-the-shelf (COTS) application AMPLPlus. Both of these entities are necessary to make the system work, and are not consumed by the process itself. This is why they are considered mechanisms. The RDdss manager is the one who points and clicks on the buttons of the RDdss, making it operate. AMPLPlus is the application containing the mathematical model used in making optimal Marine-to-school assignments. It interfaces with the CPLEX algorithm that actually performs the optimization.
III. MODELING THE RECRUIT DISTRIBUTION PROBLEM

We model the recruit distribution problem as an assignment problem. Various submodels are developed to compute input parameters and perform other preprocessing steps for the assignment model, which optimally assigns recruits to a school class. Following is a discussion of important points concerning the recruit distribution problem.

1. Schools and Classes: there are about 130 schools per fiscal year, which are broken down by classes (about 1800 classes per fiscal year). Classes of the same school, commencing on different dates, are identical. However, a class commencing soon after a recruit is available for training has greater utility than another class starting at a later date. On average, there are 600 classes in a run.

2. Program Enlisted For (PEF)
   (a) 65-70% of enlistees enter the USMC under a guarantee (or PEF). The remaining recruits enter under an open contract (PEF=00).
   (b) A recruit can be assigned only to schools associated with his or her PEF. Some PEF's are associated with one school, while others are associated with many schools.

A. OPTIMIZATION OBJECTIVES: FIT AND FILL

Our approach in the assignment model is to optimize by looking at both fit and fill. The importance of both these objectives was discussed in Chapter II, Section B. The idea is to allow the RDisss manager to make a tradeoff between fit and fill.

The high-level objective function is:

- Maximize

\[ K_1 \cdot \text{Fitness} - K_2 \cdot \text{Penalty} \]

Where \( K_1 \) is the fitness coefficient and \( K_2 \) is the fill coefficient.
By assigning different values to these coefficients, the RDdss manager is able to make trade-offs between fit and fill. This capability makes the assignment model flexible. It provides the RDdss manager a means for "gaming" the system.

B. MEASURING FITNESS

The first half of the high-level objective function deals with maximizing the fitness of Marines to schools. Therefore, we cover this topic now. Following is a discussion of important points concerning the measuring of fitness.

1. Marines are only eligible for assignment to schools corresponding to their PEF guarantees.

2. Associated with each school are specific mandatory properties, or minimum eligibility requirements (e.g. AGE > 18).

3. Eligibility of a Marine to a school is pre-determined by comparing a Marine's attributes (e.g. Age = 20) to the school's mandatory properties. A Marine is eligible only if he or she meets all the minimum school requirements.

4. Many schools also have desirable properties associated with them. This is a property which is desired in a Marine (e.g. Height > 65 inches), but are not prerequisites for attending the school. Since some desirable properties are more desirable than others, a means of distinguishing the properties is necessary. We have followed the Marine Corps practice of using 6 levels of desirability. Level 1 properties are the most desired, followed by level 2, etc.

5. Let $\mathcal{P}(s)$ denote the set of desirable properties for school $s$, and let $level(p)$ denote the desirability level of property $p$. Let $possesses_{(m,p)} = 1$ if Marine $m$ possesses property $p$ (0 otherwise). Further, let $Score_{level(p)} > 0$ be the score assigned for possessing a $level(p)$ property, where $Score_{level(p)}$ is calculated using an exponential function inversely proportional to $level(p)$. The scores for levels 1 through 6 are shown in Figure 5.

6. The total fitness score $(fit_{m,s})$ of Marine $m$ to school $s$ is composed of two parts: the score $(ManScore_{m,s})$ for possessing mandatory properties, and the score $(DesScore_{m,s})$ for possessing some or all of the desirable properties.

Our procedure for computing fitness scores is designed in a manner that, for each school, the average fitness score—with the average computed over all qualified Marines, i.e. Marines who have met the mandatory properties—is constant (i.e. 100). The reason we did this was to ensure each school
Figure 5. Exponential Function for Calculating $\text{Score}_{\text{level}(p)}$

received equal treatment in the model, regardless of the number of desirable properties specified for each school. Otherwise, all other things being equal, the school with the greatest number of desirable properties would receive the most assignments.

7. For each school $s$, percentage weights $\text{ManWt}_s$ and $\text{DesWt}_s$ are assigned, respectively, for the mandatory and desirable properties. For example, for school $s_1$, a weight of 70% may be assigned to the mandatory properties and 30% for the desirable properties.

8. A Marine possessing all mandatory properties for school $s$ is given an initial score $\text{ManScore}_{m,s} = \text{ManWt}_s \cdot 100$. Marines who do not possess all mandatory properties for a school are given an overall fitness score of 0 for that school.

9. Of all the Marines possessing the mandatory properties, those possessing desirable properties are awarded additional points, which are weighted by the level of the property. The Marine’s score for desirable properties is computed as follows:

- The absolute score $\text{Abs}_{m,s}$, for Marine $m$ and school $s$, based on desirable properties is

$$\text{Abs}_{m,s} = \sum_{p \in P(s)} \text{Score}_{\text{level}(p)} \cdot \text{possesses}(m, p)$$

The average of these absolute scores is computed over all qualified Marines. Let $\text{AveAbs}_s$ denote the average absolute score for school $s$. 

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• Each Marine's fitness score for desirable properties is then computed as a fraction of this average, and normalized by multiplying with the percentage weight for desirable properties. That is, \( \text{DesScore}_{m,s} \) is a weighted relative score:

\[
\text{DesScore}_{m,s} = \left( \frac{Abs_{m,s}}{\text{AveAbs}_s} \right) \cdot \text{DesWt}_s \cdot 100
\]

The overall average of all these scores is, due to the above construction, \( \text{DesWt}_s \cdot 100 \).

10. The final fitness score, \( \text{fit}_{m,s} \), is simply the sum \( \text{ManScore}_{m,s} + \text{DesScore}_{m,s} \). It may be seen that, for each school, this number averages (over all the qualified Marines for that school) to 100.

11. As mentioned earlier, schools are broken down by classes that are identical, except for their start dates. Therefore, let \( \text{fit}_{m,s} = \text{fit}_{m,c} \) for each class \( c \) of school \( s \).

C. MEASURING FILL

The second half of the objective function deals with maximizing the fill of school seats. We now turn our attention to this topic.

As we discussed in Chapter II, school seats are paid for in advance. This is to guarantee the seat is available to the USMC. Consequently, every vacant spot is potentially a lost resource. Since the model is run about once every week, the biggest concern is the unfilled seats having report dates within the next seven days. Conversely, a seat having a report date in three months is not so critical.

To capture the essence of filling school seats with early report dates, we use a penalty function. The idea is simple. School seats having an early report date get a high penalty, and those having a late report date get a low penalty. A number of functions would have worked for this. We have graphed two candidates in Figure 6. The first is a linear function and the second a large-step function. Each of these was tried in the prototype. In our opinion the latter one is the best choice. It gives a lot of emphasis to the first week, plus it treats all schools having report dates within the same week equally. It is the function currently implemented in the rddss.
D. ASSIGNMENT MODEL

We are now ready to formally describe the assignment model. We will first specify the model's assumptions. Then, we will list the model's notation, followed by its objective function and constraints.

1. Assumptions
   1. Each school is unique and identifies a single course of instruction leading to an MOS.
   2. In any given run, a school may offer several classes that start on different dates. It is more desirable to fill seats in classes starting earlier. Such classes have a higher penalty per unit shortfall than similar classes starting at a later date.
   3. All Marines available for assignment are graduating from the MCRD on the same date.
   4. A Marine's eligibility for a school, as well as the fit for each school, is determined by the model preprocessor, taking into account the PEF guarantees, and the mandatory and desirable properties.
   5. A Marine is assigned to a school corresponding to their PEF code, or not at all.
   6. It is better to leave a Marine unassigned than to overfill a school.
7. The demand for the number of Marines to be trained in each school class is determined by looking at the BNA extract. This demand statement is already constrained by the capacity constraint at each school.

2. Notation

- Sets
  \[ \mathcal{M} : \text{Marines} \]
  \[ \mathcal{C} : \text{Classes} \]

- Exogenous Variables (Parameters in AMPL)
  \[ \text{fit}_{m,c} : \text{the desirability of assigning Marine } m \text{ to class } c \text{ (note: the fitness score is zero for Marine-class pairs where either the Marine does not meet the classes mandatory properties, or where the class does not fulfill the Marine's PEF guarantee.)} \]
  \[ \text{demand}_c : \text{demand for Marines to be trained at class } c \]
  \[ \text{penalty}_c : \text{penalty for each unit of demand not met (higher value means it is more critical to fill the class)} \]

- Decision Variables
  \[ x_{m,c} \text{ (binary integer): 1, if Marine is assigned to the given class; 0 otherwise} \]

3. Objective

Maximize the Total Utility: (Total Reward - Total Penalty)

\[
TU = k_1 \left( \sum_{c \in \mathcal{C}} \sum_{m \in \mathcal{M}} \text{fit}_{m,c} \cdot x_{m,c} \right) - k_2 \left( \sum_{c \in \mathcal{C}} \text{penalty}_c \cdot (\text{demand}_c - \sum_{m \in \mathcal{M}} x_{m,c}) \right) \quad (III.1)
\]

4. Constraints

- assignmentLimit: a Marine is assignable to at most one school
  \[
  \sum_{c \in \mathcal{C}} x_{m,c} \leq 1 \quad \forall \ m \quad (III.2)
  \]

- eligibility: a Marine is only assignable to a class they are fit for (this prevents assigning Marines with a fitness score of zero)
  \[
  x_{m,c} \leq \text{fit}_{m,c} \quad \forall \ m \ \forall \ c \quad (III.3)
  \]
- capacity: since penalties apply only if there is a positive shortfall, the objective function would be non-linear. To avoid that, we assume we will never oversupply Marines to schools, resulting in:

\[
\sum_{m \in M} x_{m,c} \leq demand_c \quad \forall c
\]  

(III.4)
IV. A DECISION SUPPORT SYSTEM FOR RECRUIT DISTRIBUTION

A. ARCHITECTURE AND IMPLEMENTATION

Following is a discussion of the RDbss architecture and its implementation. First, the architectural components are discussed. Then, the steps taken to build the RDbss are described.

1. Architecture

The architecture of the RDbss is depicted in Figure 7. This illustration shows how the six major components of the system are related. We will describe this architecture by examining each component in the following order: switchboard, relational database, preprocessor, assignment model, solver, and analyzer.

The switchboard is one of two components providing an interface between the user and the RDbss. It is the mechanism by which the user controls the operation of the system. Figure 8 illustrates the main switchboard of the RDbss. It is displayed

![Diagram of RDbss Architecture]

Figure 7. RDbss Architecture
when the application is started. As this illustration depicts, the user can perform the following functions by simply pointing and clicking on the appropriate button: import and export data, maintain data, preprocessing and execution of the assignment model, analyze results, query data, and generate reports. All the RDdss switchboards were generated using Access 97.

The relational database technology was used in the RDdss [Ref. 8]. The actual table relationships are shown in Figure 9. These tables were developed in Access 97, which uses the relational technology. In addition to a few flat files used to communicate with the assignment model, all the data for the RDdss is stored in this database.

The preprocessor is one of the two modeling components. It consists of Access 97 Visual Basic for Applications (VBA) code that computes information necessary for the assignment model [Ref. 9]. It determines the demand of each class, the appropriate penalty associated with each class, and the Marine-to-class fitness matrix. The code for these assignment model inputs is found in Appendix D, lines 452-516 and 4305-4812.
The assignment model is the other component of the modeling components. It has been modeled in AMPL [Ref. 10], a language and a computing environment for expressing, solving, and analyzing mathematical programming problems (minimizing or maximizing a function of decision variables, subject to constraints on the variables). A complete discussion of the assignment model's math model is available in Chapter III, Section D.

The next component is the solver. It communicates directly with AMPL, the modeling language of AMPLPlus. As mentioned in Chapter II, it uses an algorithm called CPLEX, which is an optimization package for linear, network and integer programming. Working in conjunction with AMPLPlus, the solver finds an optimal solution.

The final component is the analyzer. It is the other component making up the user interface. This is where the RDdss manager analyzes assignment results, seeking insights for developing a "good" solution. Insight is developed mostly by the graphs and numerical information available in the analyzer. These were generated in Access 97 using its report generator and VBA code. The programming used in the analyzer is shown in Appendix D and includes lines 1-310, 2156-2214, and 3756-3827.
2. Implementation

Building the RDdss was an iterative process. Some steps took numerous iterations, and some were straightforward. Below is a listing of the 14 major steps it took to build the RDdss.

1. Analyzing the current system was the first step. This included 1) interviewing USMC and DSAI personnel, 2) reviewing available documentation, and 3) operating the RDM.

2. After gathering the current system data, it was necessary to develop a logical understanding of the system. This was accomplished by modeling it with BPWin. Appendix B is the result of this step.

3. With this system understanding, it was possible to envision how the new system would make assignments. Using standard optimization techniques [Ref. 11], a small-scale demonstration solver was built using Excel 97. It is shown in Figure 10.

4. Combining the system understanding and the data requirements for the demonstration solver, it was possible to envision a data structure for the reengineered system. This lead to the development of a third normal form relational schema for the RDdss [Ref. 3].
5. Using the relational schema as a model, the RDdss tables were built in Access 97. The results of this were seen earlier in Figure 9.

6. As the vision for the reengineered system came more into focus, an intuitive navigational scheme was conceived. This lead to the development of a decomposition diagram for the RDdss. It is demonstrated in Figure 11.

7. Using the decomposition diagram as a model, the user interface was built for the RDdss in Access 97. The Main Switchboard was seen earlier in Figure 8.

8. With the switchboards now in place, VBA coding was commenced [Ref. 9]. This made each switchboard functional and useful.

9. Building upon the concept of the demonstration solver from step 3, a formal mathematical assignment model for the RDdss was developed. This was introduced in Chapter III, Section D.

10. The COTS applications, AMPLPlus and CPLEX were installed on the personal computer containing the RDdss.

11. With AMPLPlus now installed, it was possible to code the assignment model into the application. This made it possible to verify our design.

12. Manually creating input files for AMPLPlus is time consuming. So, the preprocessor was coded. This automated the generation of the class demand, class penalty, and Marine-to-class fitness matrix.

13. Further automation of the RDdss was accomplished by interfacing Access 97 and AMPLPlus. This required both VBA and AMPL coding. The end result was a seamless operation of the two applications.
14. Finally, much thought was given to ways of gaining insight into the assignment results. This lead to the development of the analyzer, which was discussed briefly in the previous section.

Some of these steps were performed in parallel. The actual order followed in building the RDdss are depicted in Figure 12.

B. USING THE RECRUIT DISTRIBUTION DECISION SUPPORT SYSTEM

In this section, we will discuss using the RDdss. Three aspects are covered, 1) setting up a run, 2) model execution, and 3) customizing a run and results. Each is discussed in the order given here.

1. Setting up a Run

Setting up a run of the RDdss is straightforward and easy to do. Figure 13 graphically illustrates the steps involved. Starting with step 1 on the graph and working through to step 3d(iii), we will discuss a run set-up.

The RDdss manager starts at the top of the Main Switchboard. Here, he or
Figure 13. Setting up a Model Run

she clicks on the Import/Export Data button. This will cause the Main Switchboard to close and the Import/Export Switchboard to open. From this switchboard, the RDdss manager will import the RD1 file and the BNA extract into the RDdss MODS. This is easily accomplished by clicking on the corresponding buttons for importing these files. Finally, the RDdss manager will click on the "Return to Main Switchboard" button, causing the Import/Export Switchboard to close and the Main Switchboard to reopen.

The next step is data maintenance. This includes updating, editing, and/or deleting of school related information. The RDdss manager gets to the Maintain Data Switchboard by clicking on the appropriate button on the Main Switchboard.

From the Maintain Data Switchboard, the RDdss manager will start at the
top and work his or her way down to the bottom. The various buttons on this switchboard open forms where data maintenance is performed. For instance, the first button opens the Maintain School Data form, allowing the RDdss manager to create, edit, and/or delete a school. The other buttons allow similar operations with the PEFs, and fundamental and logical properties. After the RDdss manager has finished maintaining the data, he or she returns to the Main Switchboard by clicking on the “Return to Main Switchboard” button.

After data maintenance, the RDdss manager is ready to perform data preprocessing in preparation for a model run. By clicking on the Preprocessing and Execution button, the Main Switchboard closes and the Preprocessing and Execution Switchboard opens. From here, as on all other switchboards, the RDdss manager starts at the top and works down.

The first three preprocessing buttons directly affect the generation of the class demand, class penalty, and Marine-to-class fitness matrix. This is why they come before the fourth button, Generate AMPL Files. Preprocessing in the correct order will reduce the amount of time spent setting up the run, by minimizing the need to generate a new class demand, class penalty, and Marine-to-class fitness matrix.

The first preprocessing button concerns special assignments. Specially assigning a recruit affects the AMPL input in two ways. First, the respective member is not included in the Marine-to-class fitness matrix, since they already have an assignment. Second, the class demand for the class the recruit is assigned to must decrease by one. Otherwise, it may become overfilled.

The second preprocessing button concerns reclassification of a Marine. Reclassified Marines affect the AMPL input in two ways. First, the class demand of the class they are no longer assigned to must increase by one. This provides an opportunity to fill the empty seat during a subsequent run. Second, the class demand of the class the Marine has been reassigned to must decrease by one. Otherwise, it may become overfilled.
The third preprocessing button concerns data scrubbing, which also affects the AMPL input. It is an attempt to identify and correct errors relating to the Marines. An example is a Marine who has been given an unknown PEF. Since it is not identified by the RDdss, the member will receive a zero fitness score for every class. This will prevent the Marine from getting an assignment.

Following the completion of special assignments, reclassifications and data scrubbing, the RDdss manager is ready to generate the AMPL input files. After going to the Generate AMPL Files form, the first concern is specifying the weights for the mandatory and desired properties. This is specified by the RDdss manager at step 3d(i). What this does is indicate how important the mandatory properties are with respect to the desired properties. For instance, if the RDdss manager decided to give a weight of 1.0 to the Mandatory selection, the Desired selection would automatically fill in with 0.0. This would indicate the desired properties are of no consequence. The default for these two selections is 0.7 for Mandatory, and 0.3 for Desired.

Next, at step 3d(ii), the RDdss manager selects the MCT graduation date desired. This is selected from the drop down list. Then, the RDdss manager pushes the “GO!” button. The system will now generate the AMPL input files, completing the run set-up.

2. Model Execution

Execution of the assignment model takes place after the run set-up has been completed. Figure 14 graphically illustrates the steps taken to execute the model. A discussion of this is now given.

From the Main Switchboard, the RDdss manager points and clicks on the Preprocessing and Execution button. This takes him or her to the corresponding switchboard. From here, the Execute Solver/Options selection is made. This opens up the form where the model is executed from.

The Execute Solver/Options form provides the RDdss manager the ability to set the fit and fill coefficients for the objective function. The default values are 1 for
each coefficient. The RDdss manager can change either of these with a whole number from 0 - 100. The significance of these numbers is discussed in detail later in this chapter. Once the desired coefficients have been chosen, the Execute Solver button is pushed.

By selecting the Execute Solver button, AMPLPlus is launched. This application will run without user interaction. First, it will import the RDdss mathematical assignment model. Next, the specified fit and fill coefficients are retrieved. Finally, the preprocessed data generated during the run set-up are imported. Using this input data, AMPLPlus works in conjunction with the solver and generates an optimal assignment solution.
With the generation of an optimal assignment solution, the results are sent to an output file called “rdm.out.” AMPLPlus, having completed its task, now closes. This indicates an optimal solution was found and is available for importing. So, the RDdss manager now imports the results by pushing the Import Results button on the Execute Solver/Option form.

3. Customizing a Run and Results

As mentioned in the previous subsection, the RDdss manager can set the fit and fill coefficients of the objective function. This is a key capability of the new system. It is the means by which the RDdss manager can customize a run and “game” the RDdss. This “gaming” of the new system is essential for determining a “good” assignment result.

For instance, if the fit coefficient is set to 0, and the fill coefficient is set to a number \( > 0 \), say 1, the assignment model will maximize the fill of schools having early report dates. This has both advantages and disadvantages. One advantage is the average wait time for Marines to attend a school is minimized. Another is that the number of unfilled school seats, having a report date between the current and next scheduled model run, is minimized. However, a disadvantage is the average Marine-to-school fitness score is guaranteed to be the lowest score of all runs.

Conversely, if the fit coefficient is set to a number \( > 0 \), say 1, and the fill coefficient is set to 0, the assignment model will maximize the average Marine-to-school fitness. An advantage here is the increased chance of each Marine successfully completing their ELS, establishing a pattern of success early in their career. However, one disadvantage is the wait time for a Marine to attend a school is guaranteed to be the longest. Also, the number of unfilled school seats, having a report date between the current and next scheduled model run, is guaranteed to be the greatest.

Neither of the above solutions is ideal. A better solution is some where between these two extremes. By changing the fit and fill coefficients of the objective function, the RDdss manager has a means for customizing each run to ensure a “good”
C. INNOVATIONS IN USER INTERACTION

A number of user interaction innovations have been made in the RDdss. Two of them have already been discussed. These were the intuitive navigational scheme using the switchboards, and the elimination of manually entering data already available in the system. One more noteworthy innovation is now introduced. It is a date change innovation.

The date change innovation concerns changing the graduation date of the Marines in the downloaded RD1 file. This is necessary for generating correct assignment results. The date in the downloaded RD1 file is based on graduation from the MCRD. However, the model needs to know when the Marines are available for assignment. Availability is based on the MCT graduation date.

The old system solution to this problem took three steps. First, the RDM manager used a calendar to determine the MCT graduation date. This is normally 27 days following completion of MCRD, and is always on a friday. So, the RDM manager will find the MCRD graduation date on the calendar and count 27 days. The friday nearest to this day is the day desired. Second, this MCT graduation date, along with the RD1 file, is sent to another branch in the USMC where the date change is made. Third, the file is returned to the RDM manager, who imports the file into the RDM.

The reengineered system has streamlined this process. Within the RDdss, the RDdss manager makes the date change. It is accomplished with the push of a couple buttons.

Figure 15 shows how these changes are made. First, the RDdss manager selects the MCRD graduation date requiring a change. Once this is selected, a calendar appears. Its purpose is to help the RDdss manager correctly identify the MCT graduation date. Next, the “=” button is pushed. Its purpose is to add the number of
days specified in the “Days” field (default is 27), to the MCRD graduation date. This updates the calendar as shown on the far right. When the correct date is found, the “Change Date” button is pushed. This makes the desired change to the data in the RDdss database.

D. INNOVATIONS IN ANALYZING MODEL RESULTS

As discussed earlier, the RDdss manager has the capability of “gaming” the system by using different fit and fill coefficients. However, having this ability is not enough. The RDdss manager still needs a means to compare one run against another.

It is hard, if not impossible, to estimate the quality of a solution simply by looking at a list of assignments. The actual assignment results depend on the values of the fit and fill coefficients, which cannot be set at the ideal levels without understanding the impact on solution quality. So, analyzing run results to get insight and develop a “good” solution is now discussed.

Four measures are considered particularly useful in evaluating alternative solutions.

1. Fitness premium. The Marine-to-school fitness function is defined in a way that for each school, the average fitness over all Marines eligible for that school is 100. So, for any school, if the average fitness computed over Marines assigned
to that school is greater than (or less than) 100, the difference represents a positive (or negative) premium.

2. Unfilled seats in first week. Since the model is run nearly every week, seats left unfilled in classes starting in the first week will remain unfilled. This represents wasted resources.

3. Average wait time for Marines. Experience has shown that the longer a Marine waits before attending their ELS, the greater the chance of disciplinary problems. Therefore, it is generally better to keep this wait period short.

4. Unassigned Marines. A purpose of the system is to assign each Marine to a school. Therefore, knowing the number of unassigned Marines is an important measure.

To provide the RDdss manager insight into the assignment results, these measures have been incorporated into output representations, including summary statistics and detailed graphs. Each output provides both numerical and visual information. The numbers are used for quantitative comparisons. The graphical information provides a big picture view for use in a qualitative comparison.

As an example, consider the two fitness graphs in Figure 16. Both of these were produced using an RD1 file of 344 Marines and an BNA extract with school data covering a 120 day period. Below each graph is amplifying and numerical information. The bar chart on the left has a fit coefficient of 0 and a fill coefficient of 1. Additionally, its fitness premium is 28 (=128-100). The bar chart on the right has a coefficient of 1 for both fit and fill. Its fitness premium is 38 (=138-100). The fit numbers are quantitatively comparable. The fitness premium for the run on the right is 36% (=100% x [38-28]/28) better than the run on the left.

The above numerical analysis is also supported by visually comparing the bar charts. Notice the large number of blips falling below the fitness score of 100 on the left graph. Each blip represents a Marine, and there are actually 44 of them. Conversely, notice the comparatively small number of blips below 100 on the right graph. There are 21 of them. The visual comparison of the two graphs reveals the
qualitative difference. The graph on the right indicates a higher quality Marine-to-school fit. Of course, this supports the numerical comparison performed earlier.

As another example, consider the two fill graphs in Figure 17. These are based on the two model runs just described. In other words, the left graph has a fit coefficient of 0 and a fill coefficient of 1, and the right graph has a coefficient of 1 for both fit and fill.

Visually, these two graphs display an obvious difference. To appreciate how they are different requires an understanding of the significance of the blips. As note 1 of each graph indicates, “The classes are ordered by penalty from highest to lowest.” Recall from Chapter III, this means the ordering is by class report date, starting with the earliest date. In other words, the bar chart on the left indicates almost every Marine will start school within the first three weeks. As discussed earlier, this is desirable. The bar chart on the right has its blips more spread out. So, by visually
comparing the two graphs, the left one has a higher quality with respect to minimizing wait time.

This is easily validated by the numbers given in note 5 of each graph. The average wait of a Marine from the left bar chart is 1.33 weeks, and the average wait from the other bar chart is 1.69 weeks. Now we quantitatively compare these values. The results from the left graph are 27% (=100% x [1.69-1.33]/1.33) better than the right.

In the following table, the results from three runs are given. The measures on the left are the four measures described earlier. Each run used the same 344 Marines and 120 days worth of school classes. The information for the first and third runs is from the two model runs discussed above. The second run was determined by "gaming" the system. In other words, we tried numerous combinations of the fit and fill coefficients until a "good" solution was found. Run 2 was the result. Understand though, we are not saying "best" solution. Only the USMC can determine what is best for them.

<table>
<thead>
<tr>
<th></th>
<th>Run 1 (fit=0; fill=1)</th>
<th>Run 2 (fit=1; fill=11)</th>
<th>Run 3 (fit=1; fill=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfilled Seats (1st week)</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Unassigned Marines</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Average Wait (weeks)</td>
<td>1.33</td>
<td>1.33</td>
<td>1.69</td>
</tr>
<tr>
<td>Fitness Premium</td>
<td>28</td>
<td>31</td>
<td>38</td>
</tr>
</tbody>
</table>

The reason we feel Run 2 is a "good" solution is based on a quantitative comparison of the measures and one additional piece of information. It is the fact the USMC feels it is more important to minimize wait time than to maximize the Marine-to-school fit. The remainder of this section explains how we decided Run 2 was a "good" solution.

Starting with the values for unfilled seats, it is obvious all three runs are equal. The same is true for the unassigned Marines measure. So, these two measures provide no insight for comparison purposes.
Concerning the average wait, the values of Runs 1 and 2 are equal. Further, their 1.33 value is numerically smaller than the 1.69 value of Run 3. This is good for Runs 1 and 2. As was proven earlier, a value of 1.33 is 27% better than 1.69.

Finally, there is the fitness premium measure. The first observation made is that Run 1 is a candidate for elimination. The reason is as follows. Run 2 has the same score as Run 1 for the first three measures in the table, but it shows an 11% ($=100\% \times [31-28]/28$) increase in the fitness premium. So, Run 1 is eliminated from the competition.

This leaves the last two runs. Run 3 shows a 23% ($=100\% \times [38-31]/31$) increase in fitness premium over Run 2. This creates a conflict. Run 3 has a 27% increase in average wait time, which is bad. Conversely, it has a 23% increase in fitness premium, which is good. To decide which solution is better, more information is necessary. This comes from the fact mentioned earlier, that the USMC feels it is more important to minimize wait time than to maximize the Marine-to-school fit.

We can now conclude Run 2 is a better solution than Run 3. Here is why. Run 2 minimizes average wait by 27% by giving up a 23% increase in Marine-to-school fit. This agrees with the USMC desire to more strongly emphasize a minimum waiting time. So, Run 2 is a better solution than Run 3. Since it also satisfies the known desires of the USMC, we feel it is a “good” solution as well.

E. OBJECTIVE COMPARISON OF OLD AND NEW SYSTEM SOLUTIONS

In the previous section, we described how a set of solutions generated by the RDeSS are compared to determine a “good” solution. Using the same approach, we now demonstrate how to objectively compare the results from the old system with the new system. This provides the USMC a means of determining which system’s solution is better, if either. Comparison of the new and old system results has been made easy by automating the importing of the RDM result into the RDeSS.
We have summarized the important data for the old and new systems in the following table, based on the same 344 Marines and 120 days of school classes discussed earlier. Since the assignment algorithm for the RDM was designed to maximize fill, a run from the RDdss based strictly on fill has also been included. It is the run with a fit coefficient of 0, and a fill coefficient of 1. The last column, labeled “Run 2,” is a “good” solution we found by gaming the RDdss.

<table>
<thead>
<tr>
<th></th>
<th>Run 1 (fit=0; fill=1)</th>
<th>RDM</th>
<th>Run 2 (fit=1; fill=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfilled Seats (1st week)</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Unassigned Marines</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Average Wait (weeks)</td>
<td>1.33</td>
<td>1.34</td>
<td>1.34</td>
</tr>
<tr>
<td>Fitness Premium</td>
<td>28</td>
<td>29</td>
<td>32</td>
</tr>
</tbody>
</table>

We start by objectively comparing the RDdss fill-based result with the RDM result. They are labeled “Run 1” and “RDM,” respectively. As we shall prove, the RDdss has done a better job at filling early school seats than the RDM.

Of the four measures, only one provides any useful insight for this comparison. It is the average wait measure. The reason the other three do not apply is as follows. The first two measures have the same values, so they provide no insight. The last measure is not too meaningful, since Run 1 is strictly based on maximizing fill. In other words, it disregards fit because its fit coefficient is set to 0. This leaves the average wait measure.

A quantitative comparison of the average wait shows the RDdss solution is 1% \((100\% \times [1.34-1.33]/1.33)\) better than the RDM solution. This is explainable by considering the approach used in each model. The RDM assignment algorithm maximizes the fill of early school seats by looking at each school in a sequential fashion. In contrast, the RDdss conducts a global comparison of Marines and schools. In other words, it goes through numerous iterations until it finds an optimal fill solution. This show that the RDM assignment algorithm is only closely approximating the optimized assignment result.
Finally, we “gamed” the new system until a “good” solution was found. This is Run 2. It has a fit coefficient of 1 and a fill coefficient of 10.

The objective comparison of the RDM and Run 2 solutions is straightforward. Since the first three measures are the same for both results, they provide no insights. This leaves only the fitness premium measure. A quantitative comparison of this measure shows Run 2 has a 10% (100%\times{32-29}/29) better solution than RDM. This shows the benefit of “gaming” the RDdss.

F. SUMMARY

This relatively long chapter covered some important points related specifically to the RDdss. The architectural components of the new system were discussed first, followed by the steps taken to actually build this DSS. Then, from an operational point of view, using the RDdss was discussed. This included setting up a run, executing the model, and customizing a run for determining a “good” solution. Next, two innovations were discussed in great detail. These included the date change innovation and the analyzing model results innovation. Finally, a means of objectively comparing the solution from the old and new systems was discussed.

We truly believe the innovations and capabilities introduced by this prototype can greatly benefit the USMC’s Marine Enlisted Assignments branch. It can help the USMC to more effectively accomplish its mission as stated by the Commandant of the Marine Corp, “to put the right Marine in the right place at the right time with the right skills and quality of life.”
V. CONCLUSION

This concluding chapter has three short sections, followed by a final comment. In the first section, we reiterate the significant contributions made in the thesis. This is followed by a brief description of some lessons we learned. Then, some recommended improvements for the prototype are given. Following this last section, we comment on how this thesis work might benefit the other branches of the United States military.

A. SIGNIFICANT CONTRIBUTIONS

Four significant contributions beneficial to the USMC were made in this thesis. These were discussed in detail in the previous three chapters. A list and summary of the contributions is given here.

- Analysis and articulation of the recruit distribution process - by interviewing USMC and DSAI personnel, reviewing available documentation, and operating the RDM we were able to articulate an understanding of the recruit distribution process using IDEF process modeling. Additional data modeling was articulated in a third normal form relational schema.

- Development of a mathematical model - by analyzing the assignment process, criteria, and constraints, USMC policies and objectives, a mathematical model for the new system was developed.

- Fully functional prototype - an intuitive and easy to understand new system that seamlessly interfaces with the old system was built. It provides an objective means of comparing assignment results of both systems, and was developed using COTS software applications.

- Elimination of the proprietary solver and associated contractor lock-in - this was accomplished by replacing the proprietary solver with two COTS applications.

B. LESSONS LEARNED

Our original goal was to build an As-Is IDEF0 model of the RDM, about two months after starting the thesis. This worked out fine. The next goal was to take
another six weeks to develop a To-Be IDEF0 model [Ref. 1]. This did not work out, for two reasons. First, our understanding of the entire recruit distribution process was still not mature enough to build the To-Be model. Nearly half a year was spent just thinking about its many details. Second, it is nearly impossible to envision the new system without first knowing the capabilities and limitations of the application used to build the prototype. One extreme envisions the impossible, while the other barely touches the reengineered system's potential. The lesson learned from this was that properly reengineering a process requires two things. A detailed understanding of the current process environment, and a good working knowledge of the capabilities and limitations of the application used to build the prototype.

Getting feedback from the Marine Enlisted Assignments branch was not always easy. Correspondence normally occurred by e-mail. There was an inverse relationship between the number of questions asked and the number of answers given. As the one increased, the other decreased. So, another lesson learned was that it is best to limit each correspondence to a question or two.

While writing code, it is best to simultaneously document the code's purpose. Going back and trying to provide documentation at the end is too frustrating. This requires a considerable amount of discipline, but is well worth the effort. The lesson learned here is document as you code.

C. PROTOTYPE IMPROVEMENTS

A big part of this thesis involved the building and refinement of the prototype. The following topics are areas where the RDdss could use improvements.

1. Speed Improvements
   a. Preprocessing Data

   Of all the steps necessary to complete a run of the RDdss, the preprocessing step is the most time consuming. For the 344 Marines and approximately 500 school classes analyzed in this thesis, it takes about 30 minutes to preprocess
this data. This is about ten times longer than the assignment model takes to find an optimal solution. As the size of the preprocessing data is doubled, so is the time needed to preprocess it. Finding a way to speed up this process is desirable. One possibility is to find a way to perform all the preprocessing in main memory, with only two accesses to the hard drive. The first access is to get the necessary Marine and school data. The second is to write the preprocessed results back to the hard drive.

b. Analyzing Result

Compared to all other forms and switchboards in the RDdss, opening the "analyze results" forms is the most time intensive. With the 344 Marines and approximately 500 school classes, it takes just under a minute for any of these three to open. This feels like an eternity when you are in a hurry. The reason it takes so long is the creation of temporary tables, numerous calculations and comparisons, and retrieving of data from flat files. Finding a way to reduce this time is desirable. One possibility is to create another form which would contain only the four objective measures. Currently, the RDdss manager must go to two different forms for this information. Each containing information and displays in addition to the objective measures, which slow them down.

2. Multiple Solution Storage

Currently, the prototype will only save the results of one solution. This means the RDdss manager must either print-out hard copies of the graphs, or manually write down each solution's objective measures for comparison with other runs. An improvement here should allow the storage of at least three solutions. This would permit the RDdss manager to easily compare each solution. He or she could then eliminate one or two undesirable solutions, while continuing to search for a "good" one.
3. **Administration Switchboard**

To look at all the schools or properties in one display, the RDaSS manager must open up the associated school or property table. A reason for doing this is system administration. For instance, if a supervisor is auditing the RDaSS's property data, looking at all the data at one time is convenient. A simple way of including this feature is by adding another switchboard. The switchboard’s buttons would have VBA code associated with them, causing the desired tables to open.

Any benefits derived from this thesis work were specifically aimed at the USMC. However, it does not have to end there. Like the USMC, other branches of the United States military must deal with the problem of how best to assign their service members to schools. Since all the services require their enlisted personnel to take the ASVAB test, the approach used in our prototype might prove an ideal solution. Further, our efforts may also contribute to the reengineering of other assignment models. So, this thesis work could actually benefit all branches of the United States military.
# APPENDIX A. ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPL</td>
<td>A Modeling Language for Mathematical Programming</td>
</tr>
<tr>
<td>ARMS</td>
<td>Automated Recruit Management System</td>
</tr>
<tr>
<td>ASVAB</td>
<td>Armed Services Vocational Aptitude Battery</td>
</tr>
<tr>
<td>BNA</td>
<td>By Name Assignment System</td>
</tr>
<tr>
<td>BPWin</td>
<td>Business Process for Windows</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial-off-the-shelf</td>
</tr>
<tr>
<td>CPLEX</td>
<td>Optimization Package for Complex Linear, Network and Integer Programming</td>
</tr>
<tr>
<td>DSAI</td>
<td>Decision Support Associates, Inc.</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>ELS</td>
<td>Entry Level School</td>
</tr>
<tr>
<td>ICOM</td>
<td>Input, Control, Output, Mechanism</td>
</tr>
<tr>
<td>IDEF</td>
<td>Defense Institute Modeling</td>
</tr>
<tr>
<td>IDEF0</td>
<td>Business Process Modeling</td>
</tr>
<tr>
<td>MCRD</td>
<td>Marine Corps Recruit Depot</td>
</tr>
<tr>
<td>MCT</td>
<td>Marine Combat Training</td>
</tr>
<tr>
<td>MODS</td>
<td>Military Operational Data Store</td>
</tr>
<tr>
<td>MOS</td>
<td>Military Occupational Specialty</td>
</tr>
<tr>
<td>PEF</td>
<td>Program Enlisted For</td>
</tr>
<tr>
<td>RD1</td>
<td>Recruit Distribution Input File</td>
</tr>
<tr>
<td>RD3</td>
<td>Recruit Distribution Output File</td>
</tr>
<tr>
<td>RDDSS</td>
<td>Recruit Distribution Decision Support System</td>
</tr>
<tr>
<td>RDM</td>
<td>Recruit Distribution Model</td>
</tr>
<tr>
<td>USMC</td>
<td>United States Marine Corps</td>
</tr>
<tr>
<td>VBA</td>
<td>Visual Basic for Applications</td>
</tr>
</tbody>
</table>
APPENDIX B. AS-IS RD BUSINESS PROCESS (IDEF0) MODEL
APPENDIX C. TO-BE RD BUSINESS PROCESS (IDEF0) MODEL
null
DELETE DISTINCT MARINE.*, ASSIGNMENT FROM MARINE
INNER JOIN ASSIGNMENT ON MARINE.SSN_FN = ASSIGNMENT.SSN_FN
WHERE
ASSIGNMENT.ReportCode = 'A' AND MarineCode = M
WHERE (ASSIGNMENT.SSN_FN is null)
GRN 7 'Fire is deleted'
'No action taken'
End Select
End Sub
LIST OF REFERENCES


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