MANPOWER, PERSONNEL, TRAINING, AND QUALITATIVE ANALYSIS SYSTEM (MPTQ): A SAS® Software-Based Application to Satisfy DoD Requirements

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1.0 INTRODUCTION

Manpower, Personnel, Training, and Qualitative Analysis System (MPTQ) is an interactive SAS software application system. The MPTQ system was developed by HAY Systems, Inc. to perform Manpower, Personnel, Training, and Qualitative analyses. As a result of a bill passed by the U.S. Congress, the MPTQ analysis is performed by the DoD and the DoD prime contractors on a variety of weapon systems. This type of analysis provides the weapon system developers and the Manpower and Personnel Integration (MANPRINT) staff with the capability of conducting a timely analysis to study and support the impact of the design recommendations on the Manpower, Personnel, and Training requirements. All the DoD branches require weapon system developers and designers to provide this type of analysis to show the MPT future requirements and the cognitive requirements for those personnel who would be operating these new weapon systems.

This paper will provide an overview of how this SAS application system works, its components and capabilities, the SAS products used to develop this system, and finally the future enhancements planned for this system.

The features and flexibility of the MPTQ system are made possible by the powerful capabilities of the SAS Software. This overview demonstrates an example of utilizing the SAS language and several of its products.

2.0 OPERATING SYSTEM ENVIRONMENT AND SAS PRODUCTS

The MPTQ system was developed to operate in the MVS/TSO environment. It is a menu driven system that utilizes most of the capabilities of the SAS base software, SAS Macro language, SAS/FSP software, SAS/AF software, SAS Autocall facility in batch and interactive mode, and TSO clists.

Although SAS Version 6.18 was used to develop the MPTQ system, the Cognitive Requirements Model, the "Qualitative" portion, was downloaded from the TSO mainframe environment to the PC DOS environment. SAS micro-to-host link product was used in the downloading process and also in the process of converting the code to run in a SAS version 6.03.

Given the flexibility of the SAS language, it would be possible to go through a conversion process to run the MPTQ system under CMS, the Digital Equipment Corporation's VAX/VMS, the Hewlett-Packard's HP 9000 series and series 800 under HP-UX, the SUN Microsystems under SUN-OS Release 4.0, and the IBM Corporation's PS/2, PC AT and compatible machines under MS-DOS and PC-DOS.

By the very nature of any software application, the storage requirement and processing power are a reflection of the size of the data files which will be handled, the number of computations which will be executed at any given time, and the complexity of the user interface. The MPTQ system requires a nominal amount of storage for itself. Thus, the performance level a user desires should be the primary factor in selecting a particular machine environment.

3.0 OVERVIEW

As in any interactive menu driven system, the MPTQ system was designed to be a user-friendly system operable by any analysis team. The SAS/FSP product was used extensively in collecting, editing, and browsing all data files. Ample instructions and guidance were built in the system. The SAS/AF product was used in designing menus and screens to capture the user's requests throughout the analysis session.

The MPTO System incorporates four computational modules; manpower, personnel, training resources, and cognitive requirements. All the Data files required to run MPTO analysis are stored as SAS data sets in a central SAS data library. Each module uses appropriate data set(s) from the SAS data library along with user inputs and assumptions to establish parameters to run the requested analysis.

Module outputs are available as hard copy reports for the user and provide input data for other modules. For instance, conducting a Manpower analysis will enable the user to produce Manpower analysis report(s) and create additional temporary data sets that will be used to conduct Personnel analysis, Training analysis, or both. Files for storage of outputs are provided preserving both the computational results and relevant user assumptions for subsequent on-line reference.

Operation of the modules is controlled by the user via a series of menus and interactive screens. Execution of the Manpower, Personnel, and Training Resources modules, which constitute the "quantitative" portion of the MPTQ System, can be conducted separately or combined. The Cognitive Requirements Module, which constitute the "qualitative" portion of the MPTQ system, is controlled independently.

For quantitative projections, the MPTQ System incorporates the algorithms used by the U.S. Army for projecting the requirements of developmental systems and/or used in actual manpower and personnel management activities. For qualitative requirements projections, the Cognitive Requirements Model (CRM®), developed by HAY Systems, Inc., is incorporated. As a stand-alone model, the CRM® has been applied to numerous Army systems for clients in both the government sector and various industries, with documented success in system MANPRINT programs.

A schematic of the overall design of the MPTQ System is depicted in Figure 1. The central SAS data library is shown which contains nine SAS data sets. These nine SAS data sets remain relatively constant over time, but can be readily changed as basic parameters or assumptions are revised by the user. Both tape and interactive edits are used for the primary sources of data indicated in Figure 1. In terms of volume, the LSAR data set provides most of the data stored in the central SAS data library. LSAR stands for Logistics Support Analysis Records which is provided by the U.S. Army.
Brief Flow Chart of the MPTQ System

Figure 1
Several types of edits were built in the MPTO System to protect against possible unintentional mistakes a user could make. For instance, adding a new observation to one of the SAS data sets with a duplicate value in a key field. This was accomplished by allowing the user to edit a temporary copy of the master data set, then subjecting the temporary data set to an editing process. PROC SORT, FIRST, and LAST processing, and a comparison between the temporary SAS data set and the permanent SAS data set were the basic steps that constituted the editing process.

4.0 HOW DOES THE MPTQ SYSTEM WORK

In this section a brief description of how the system works will be presented. As explained before, the Qualitative Analysis portion of the system is independent and can be performed separately. The Quantitative Analysis portion consists of two modules. The two modules are the Data Load Module and the Manpower, Personnel, and Training Module. The two modules complement each other. Any change made in the Data Load Module will have a direct effect on the MPT analysis.

4.1 QUANTITATIVE ANALYSIS PORTION (MPT)

This portion of the system is the most complicated one. It uses three basic sources for its operation. These sources are:

- Data Load Module - Data source
- MPTMAC - A SAS macro library which houses all macros used in the interactive session.
- BTCHMAC - A SAS macro library which houses all macros used by the batch job at batch execution time.

The goal of this process is to produce a tailored SAS batch job that would perform the analysis described by the user and produce the requested report(s). Figure 2 illustrates this process and will be explained in detail.

The process starts with selecting an option from the MPTO main menu to perform an MPT analysis. The user then goes through Manpower Analysis screens, Personnel Analysis screens, and finally Training Analysis screens. This sequence of events is intended because of the dependency between the three types of analyses that were explained before. However, the user is not forced to perform all three analyses, but can stop after any one of them.

Each analysis has two phases. In the first phase, the user describes how he or she wants to perform the analysis by either accepting the baseline default assumptions or varying basic assumptions and performing "what if" types of analysis. In the second phase, the user can request any number of reports from a special menu for every analysis. "Stop and perform the analysis" is another option in addition to "Cancel the analysis" and "Return to MPTQ main menu". The Manpower Reports menu offers eleven different reports; Personnel Reports menu offers three, where Training Reports menu has eight different reports.

The core of this process is a very elaborate macro called BTCHWRTR (Batch Writer). The product of executing this macro is an external file that contains the SAS batch job. The AF shell takes the user's order, then stores the order in global macro variables. By definition, the global macro variables would be available to BTCHWRTR which then writes a customized SAS batch job to an external file, and submits the batch job to TSO for execution.

BTCHWRTR, as shown in Figure 2, requires several parameters. The data comes from the DATA source, the Data Load Module. The analysis parameters come from AF via global macro variables, and finally the batch job execution parameters are also specified in AF via global macro variables. The Batch job execution parameters are specified by the user when he or she elects to stop and perform the analysis. This is done by displaying an AF program screen where the user can specify:

![Diagram of producing a batch job](image-url)
• User last name
• User TSO ID
• TSO Accounting Number
• Class parameter
• Priority
• Produce hard copy of requested reports or save
  reports to an external file
• Save a new image of the LSAR file

If the user wishes to save the reports to an external file,
he or she provides a five character name for the external file.
BATCHWRTR adds the three letters MPT

write a macro call in the SAS batch job for the corresponding
writes macro calls to macros which resides in the macro library
BATCHMAC. The macro library BATCHMAC stores a separate macro
for every report available in the MPTO system. All the
BATCHWRTR macro has to do to produce requested report(s) is to
write a macro call in the SAS batch job for the corresponding macro.

The two macro libraries MPTMAC and BATCHMAC are
accessible to the MPTO system and to BATCHWRTR by means of
the SAS autocall facility.

This design offers a tremendous amount of flexibility in the
developing phase of the system. It also provides the user with
the ability to determine when the batch job should run depending
upon the time sensitivity of the analysis. And finally, because of
this design, the interactive session of the MPTO system became
nothing more than a parameter collection session which minimized the required computer resources.

4.1.1 DATA LOAD MODULE

This module is the source of data for the Manpower,
Personnel, and Training analysis module. The data stored in this
module is available to the user to manipulate and update as
necessary. This module consists of the following components:

• Central SAS data library;
• Set of SAS/AF programs and menus;
• Set of customized SAS/FSEDIT and SAS/
FSBROWSE screens;
• Set SAS Macros.

The Central SAS data library is the only source of data for
the MPTO System. It has nine SAS data sets which contain all of
the Army information needed to perform an MPT analysis. The
nine SAS data sets are:

1. MARC Data (New and Old): Manpower Requirement
Criteria AR570-2;
2. Force Structure Information Data: Table of
Organization and Equipment;
3. LSAR Data: Logistics Support Analysis Record;
Army and Personnel Command;
5. DAPC 238 Data: Department of Army Personnel
Center (Transients, Trainees, Holdees, and
Students);
6. DMDIC Data: Defense Manpower Data Center;
   (promotion & attrition ratios)
7. Training POI Data: Programs of Instructions;
8. ATRM 159 Data: Deputy Chief of Staff Resource
Management HA TRA DOC;
9. SGA Data (Standard of Grades): AR511-201

The set of SAS/AF programs and menus is the mechanism
by which the user can communicate with the system to pass
through the different levels of the system. A main menu is
designed to start the Data Load module, and is accessible to
the user from the MPTO Main Menu. The main purpose of this menu,
as with the majority of all SAS/AF menus, is to display all the
options available to the user, the nine types of data, and to allow
the user to select one of the options. The main menu then directs
the user based on his or her selection to the proper path through
the MPTO system. The user would indicate which of the nine SAS
data sets he or she wishes to update. The process of updating
and manipulating takes place in two different manners depending
upon the size of the SAS data set in question. Since the size of
the LSAR SAS data set is very large, the only method of updating
is by means of a batch job that can be submitted through the
system. All the eight remaining SAS data sets can be updated
interactively by means of the set of customized FSEDIT screens.

The interactive updating process consists of three
options for each one of the nine SAS data sets. The user can
either add a new observation, edit existing observations, or
browse existing observations. Although PROC FSEDIT can be
used to provide the user with all three capabilities, separating
them makes it easier for beginners. By separating the three
capabilities, fewer instructions would be required on every
screen, and screens would be more readable and simpler for the
user to follow. A very significant feature was built in the MPTO
system to eliminate any confusion between the three capabilities.
This feature is displaying the data to the user in the same exact
layout. In other words, the user will always view the data in one
layout whether he or she is adding an observation, editing
existing observations, or browsing existing observations. Figure
3 shows an example of an FSEDIT screen used to allow the user
to edit existing observations in the SGA SAS data set. A proper
title appears at the top of all screens to indicate which SAS data
set it is operating on. Instructions always appear at the bottom
of all screens to provide guidance to the user.

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<table>
<thead>
<tr>
<th>Command →</th>
<th>MODIFIED STANDARD OF GRADES DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGR: (Manager)</td>
<td>1</td>
</tr>
<tr>
<td>User First Name</td>
<td>100</td>
</tr>
<tr>
<td>User Last Name</td>
<td>100</td>
</tr>
<tr>
<td>UserTSOID</td>
<td>100</td>
</tr>
<tr>
<td>Class parameter</td>
<td>100</td>
</tr>
<tr>
<td>TSO Accounting Number</td>
<td>100</td>
</tr>
<tr>
<td>Priority</td>
<td>100</td>
</tr>
</tbody>
</table>

Additional Personnel and Supervisors

| Class parameter | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| User First Name | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| User Last Name | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UserTSOID | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Class parameter | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TSO Accounting Number | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Priority | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Please F9 for next record, F7 for previous record, F3 to Save and Exit.

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Figure 3
Modify SGA SAS Data Set

Finally, the set of macros is used to prepare temporary
SAS data sets for the user to edit, browse or add to. The set of
macros also contains the SAS code that performs editing,
updating, and housekeeping after the editing sessions are
completed. These macros are called from AF which also provides
the flexibility of editing the macro code without having to use
PROC BUILD. All the macros used during the interactive MPTO
session are stored in a macro library.

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The SAS autocall capability is utilized to make all the macros in the SAS Macro Library available to AF during the interactive session.

4.1.2 MANPOWER, PERSONNEL, AND TRAINING MODULE (MPT)

As explained before, the user describes to the system how he or she wishes to perform the analysis. This is done by selecting an option (Vary Basic Assumptions) while in the first phase of performing the analysis. The parameters or assumptions that could be varied by the user are:

- Frequency of repairs for the weapon system being analyzed;
- Average time of repairs for the weapon system being analyzed;
- Force Structure;
- Usage rate of the weapons being analyzed (war time vs. peace time);
- What type of MARC data to use in performing the analysis;
- Equipment tradeoff analysis.

All these assumptions are made temporarily during the execution of the batch job enabling the user to perform "what if" type of analysis. This capability is very significant for the engineers and designers of new weapon systems during the development phase.

4.2 QUALITATIVE ANALYSIS PORTION (CRM™ MODEL)

The Qualitative Analysis Module is an option the user can select from the Analysis Main Menu. Figure 4 shows the Qualitative Analysis Main Menu where the user can exercise one of six options.

Again, as a general practice throughout the MPTQ System, the name of the current module is always at the top of all screens, and sufficient instructions are always displayed.

<table>
<thead>
<tr>
<th>QUALITATIVE ANALYSIS MAIN MENU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Add a new record</td>
</tr>
<tr>
<td>2. Delete records</td>
</tr>
<tr>
<td>3. Browse records</td>
</tr>
</tbody>
</table>

Please make your selection then press ENTER

Figure 4
Qualitative Analysis Main Menu

The Qualitative Analysis Module incorporates the CRM™ (Cognitive Requirements Model) in its operation. The result of performing a Qualitative Analysis for a given task is the cognitive requirement for the people expected to perform the task. The CRM™ model is specifically designed for the qualitative analysis of cognitive complexity of system tasks. A key aspect of the CRM™ model is its focus upon relating task complexity to the AA (Aptitude Area) level likely to be required to perform a task to current Army standards. The CRM™ Model was based upon current theory in cognitive science and human information processing and has been refined through a number of applications to system development problems.

Adding a new record indicates performing a Qualitative Analysis for a new task and storing the result of the analysis in the master SAS data set. When the analyst wants to add a new record, he or she will be asked a series of tailored questions regarding the task being examined. These questions are presented in several consecutive SAS/AF program screens. The capability of setting screen field attributes in SAS/AF is utilized. For instance, to make sure that the user has answered all questions, the required option is set for all screen variables. Another example is using the list option in the field attribute panel to list valid answers to every question.

The analyst can change or manipulate answers to these questions to determine the impact on the overall cognitive workload associated with the task being examined. For example, reducing the number of steps associated with a task may not have as much impact on the cognitive requirement as providing a job aid.

Two major elements constitute the evaluation portion of the model. The first of these elements consists of a set of rating scales for six cognitive factors. These rating scales, when applied to a given task, provide the basic input data to the Qualitative Module. The second element is an evaluation algorithm that integrates the twelve scale values into a single number in order to index the cognitive complexity of the task. The evaluation algorithm is expressed in a highly interactive, rather than linear, form in order to capture the interrelationships among the cognitive factors.

The integration function of the evaluation algorithm is a very important aspect of the CRM™ Model. Since it produces a single index of cognitive difficulty, the CRM™ can be readily used to compare many different sorts of tasks and to relate task difficulty to enlisted entry standards like ASVAB (Analytical Skill and Vocational Aptitude Battery) and AA (Aptitude Area) scores. Most of the other qualitative evaluation procedures, like the JASS system taxonomy and rating scales do not contain this feature.

<table>
<thead>
<tr>
<th>QUALITATIVE ANALYSIS REPORTS MENU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Detail Report</td>
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<tr>
<td></td>
</tr>
<tr>
<td>2. Summary Report</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>7. Exit back to TSO</td>
</tr>
</tbody>
</table>

Figure 5
Qualitative Analysis Reports Menu

Figure 5 shows the Qualitative Analysis Reports menu which is displayed at the user's request. The user selects a
and answers a few questions related to the selected report, then a batch job is submitted to produce the report. The Qualitative Analysis Module has five batch programs to produce the five reports. Each program contains the code to manipulate the data and produce the report. By operating in this manner, the user does not have to wait while the system is preparing and producing reports. The batch jobs are tailored to the client requirements and priorities. For instance, the priority and class parameters of the five batch jobs could be adjusted to the overnight shift processing.

After selecting the required report(s), two options are offered to the user. Returning back to the Qualitative Analysis Main Menu, which opens the door to a variety of other options including MPT analysis, and exiting to TSO terminating the MPTO System. Giving the user the option of terminating the MPTO System at lower menus, such as this menu, provides additional flexibility and ease to the system by not forcing the user to go back to higher menus.

In order to increase its utility, the complete CRM™ model employs two other major components, besides its scaling and evaluation procedure. The first of these components is a program to perform sensitivity analysis. This analysis is incorporated in the Qualitative module as one of five possible Qualitative Analysis reports. The sensitivity program can determine the impact of a change in any of the moderator factors (or combinations of the moderator factors) on the final difficulty measure. It can also be used to determine the distribution of cognitive factor scores required to obtain an established difficulty index. Figure 6 shows an example of a sensitivity report produced by the system.

The second additional component is a SAS data set of reference or comparison difficulty measures from previously scored tasks. Maintaining this SAS data set allows analysts to make comparisons between new systems and existing or baseline systems.

<table>
<thead>
<tr>
<th>SENSITIVITY ANALYSIS REPORT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill Level: 30</td>
<td>Y</td>
</tr>
<tr>
<td>Special Skills: Y</td>
<td></td>
</tr>
<tr>
<td>Theory: Y</td>
<td></td>
</tr>
<tr>
<td>Precision: Y</td>
<td></td>
</tr>
<tr>
<td>Assembly: Y</td>
<td></td>
</tr>
<tr>
<td>Access: Y</td>
<td></td>
</tr>
<tr>
<td>Cognitive Factors</td>
<td></td>
</tr>
<tr>
<td>Working Memory: 3</td>
<td></td>
</tr>
<tr>
<td>Quantity of Data: 5</td>
<td></td>
</tr>
<tr>
<td>Multiple Processing: 5</td>
<td></td>
</tr>
<tr>
<td>Data Interpretation: 5</td>
<td></td>
</tr>
<tr>
<td>Data Interpretation: 5</td>
<td></td>
</tr>
<tr>
<td>Problem Solving: 1</td>
<td></td>
</tr>
<tr>
<td>Decision Mapping: 2</td>
<td></td>
</tr>
<tr>
<td>Results: CLS: 43.99 AA: 130</td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderator Factors</td>
<td></td>
</tr>
<tr>
<td>Psychomotor: 3.8</td>
<td></td>
</tr>
<tr>
<td>Long Term Memory: 5.5</td>
<td></td>
</tr>
<tr>
<td>Task Repetition: 5</td>
<td></td>
</tr>
<tr>
<td>Perceived Risk: 4</td>
<td></td>
</tr>
<tr>
<td>Perceived Risk: 4</td>
<td></td>
</tr>
<tr>
<td>Time Factor: 5</td>
<td></td>
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<tr>
<td>Environment Factors: 5</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>FIGURE 6</td>
<td></td>
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</table>

Example Of A Sensitivity Analysis Report

### 5.0 CONCLUSION

The purpose of this paper was to demonstrate to SAS users an example of using the SAS System and some of its products to develop an interactive user-friendly system. The SAS System was chosen because of its flexibility and most importantly, its portability across several operating systems and hardware.

ACKNOWLEDGMENTS:

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REFERENCES:


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