Worldwide Maintenance Prediction Model for the United States Army

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ABSTRACT

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) is developing a facility maintenance prediction model for the Department of the Army. This simulation model will predict the actual activities required to maintained Army facilities; schedule all occurrences of the activities over a 10-year planning period; and calculate all labor, equipment, material, and dollar resources required to support the maintenance plan. The computer model is machine independent and currently resides on two different personal computer systems. This simulation model will be used throughout the world to develop the Army long-range planning program for facility maintenance. This model can also be applied to nongovernmental organizations for maintenance planning.

Modèle pour les Prévisions d'Entretien pour l'Armée Américaine à l'Echelle Mondiale

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ABSTRACT

Le Laboratoire de Recherche d'Ingénierie de Construction Américain (USA-CERL) est en train de mettre au point un modele pour la prévision le l'entretien de l'équipement à l'usage de l'Armée. Ce modele simulé permettra la prévision des activités réellement requises pour l'entretien de l'équipement militaire, la programmation de toutes les occurences des activités au cours d'une période de prévisions s'étalant sur dix ans, et le calcul de tous travaux, matériaux d'équipement et ressources financières en dollars nécessaires pour le maintien du plan d'entretien. Le modèle informatique est indépendant des machines et est actuellement relié à deux systèmes informatiques personnels différents. Ce modèle simulé sera utilisé dans le monde entier dans le but de développer le programme de planification à long terme pour l'entretien de l'équipement. Ce modèle peut également être appliqué aux organisations non gouvernementales pour la planification de l'entretien.

1. CURRENT MAINTENANCE PREDICTION MODELS

The Army performs maintenance (all work required to keep a facility in a standard operating condition) resource predictions at three periods during the facility life cycle. During the planning period the planners must estimate the future costs to maintain the new facility. If replacing an existing facility, the planner must state the actual maintenance requirements for the existing facility. During the design period the designers must use life cycle costs to select the most economical components. Finally, during the maintenance period the maintainers must estimate the resources required for planning and programming purposes. The Army manages its real property by dividing the facilities into different Facility Class and Construction Category Codes (F4C). Some of the F4C's, such as antennas, are small and can be managed very easily at the facility level. Other F4C's, such as family housing, are complex and composed of many systems, such as electrical and plumbing. Management of such facilities is usually performed at the system or major component level.

2. MRPM DESCRIPTION

The MRPM serves as the Army's system of record and maintains a list of all available computer tools (PAVER, ROOFER). MRPM also contains the calculation methods used by an installation to perform resource predictions. Some computer tools will be able to be applied to predict resources for a complete F4C (PAVER). Other computer tools are applicable to only one system or component of an F4C (ROOFER). The major objective of MRPM is to predict the labor, material, equipment, and dollar resources required for the planning and programming period. This is the third through eighth year from the current year. Resource summaries are produced for the component, system, facility, F4C, installation, major command, and total Army levels.

MRPM maintains a complete list of F4C codes. For each code MRPM maintains a list of available tools that can be applied to calculate resources. The simplest tool available is an annual factor method based upon a dollar per unit of measure (dollars per square foot). This method produces the same requirement for every year. The second set of prediction methods applies a standard maintenance policy to determine resource requirements. The third set of methods involves detailed maintenance programs that address such items as inspection standards, condition codes, and work requirements in addition to performing resource predictions. USA-CERL is a primary developer of maintenance management systems and coordinates all development to insure that all methods apply the same basic task resource information.

MRPM allows an installation to subdivide its facilities in geographic areas (subinstallations, areas, facility groups, individual, and apartments facilities). For research purposes each facility type has been subdivided into systems, subsystems, and components when applicable. For each component a comprehensive list of tasks or activities that must be performed during the life of a facility has been developed. The last task in the task list is always a complete replacement of the entire component. The resources and frequencies of occurrences for each task have been developed. Frequencies have been determined for the lowest, average, and highest periods of occurrence. Engineered Performance Standards (EPS) were

applied to calculate the labor resources whenever possible. Each task has been divided into subtasks and the resources for each subtask given. Material costs have been converted to equivalent labor hours by dividing the total material cost by the hourly rate for the major craftsman. Indirect costs have been determined using EPS. Research into resource requirements has shown a non-uniform distribution that varies quite drastically over time. MRPM allows the application of resource summaries or individual tasks. The longest life cycle for a replaceable component is 80 years for slate roofs; therefore, a generalized 80-year life cycle resource summary is required.

The research computer model can operate on any personal computer system supporting MS DOS. The system is menu-driven and can be applied by any member of the maintenance team with minimal training.

3. FACILITY MODELING

Facilities in the field are constructed from construction drawings. Maintenance requirements vary with the component and are also affected by the way the occupant treats the facilities, inside and outside weather conditions, initial construction quality, maintenance policy, and travel time from the shops to the facility. A facility can be modeled in a number of ways. One would be a very simple model describing only the F4C, date of construction, and square footage of floor area. At the other end of the spectrum is a complete list of all components with the facility. The methods used to maintain a facility vary from area to area. MRPM allows an installation to define six different sets of task performance methods. For example: one performance method for family housing using a contractor for all tasks, one for barracks using a contractor for roof and exterior work and the inhouse staff for all other work, one for administrative facilities using the inhouse staff to perform all tasks. MRPM contains multiplication factors to account for variances in occupant behavior, weather conditions, original workmanship, and maintenance policies. Direct resources for labor, material, and equipment are stored for each task and summarized for components, subsystems, and systems. Indirect task resources based upon EPS are included through the use of direct task resource multipliers. A travel zone multiplier is used to reflect travel time from shop to facility. Actual labor and equipment rates are given for inhouse and contractor work.

4. FACILITY MODELING EXAMPLES

A facility can be modeled in many different ways. The exterior walls and roof systems will be used to illustrate the various methods on modeling. Assume an example facility composed of 2,700 square feet of floor area. The roof is constructed of 1,600 square feet of built-up roofing and 1,400 square feet of shingles. Exterior walls are composed of 8,000 square feet of clay brick, 6,000 square feet of concrete block, and 8,000 square feet of wood siding.

The simplest model would be to use only one feature of the facility, 2,700 square feet of floor area. MRPM would take this one feature and calculate a resource estimate by applying an Army average resource requirement based upon floor area.

The facility could be modeled a second way by using all the major components with the total square footage of the component. Example: (1) 3,000 square feet of built-up roof, and (2) 22,000 square feet of wood siding, etc.

MRPM would take the specified components and calculate a resource estimate in one of two ways: (1) MRPM could apply the complete list of all tasks required to be performed for each component and calculate a resource requirement. At the task level the actual labor trades performing each task would be known and actual resource rates would be used to calculate the resource costs. MRPM would be able to report the labor hours for painters, carpenters, masons, and roofers as well as the equipment requirements for each trade. (2) MRPM could apply a summary component resource requirement. The summary would have been previously calculated using the actual tasks to determine basic resource requirements. The major craft would be applied to the component summary. MRPM would not be able to report actual labor hours for painters, carpenters, masons, and roofers. The dollar value calculated by method 2 would be close to the dollar value calculated by method 1. The speed of computer calculation would vary between the two methods. If on the average every component had five tasks, the second method would require 20 percent of the computation time of the first method.

The facility could be modeled a third way by using the exact components and quantities that are in the facility. Either calculation methods 1 or 2 as described in Model 2 can be applied.

It is not necessary to describe the facility at the same level of detail for every system or subsystem. The roofs and walls can be defined at the detailed component level while the electrical, plumbing, and HVAC systems could be modeled by the total floor area of 2,700 square feet. MRPM will calculate the resource costs using both tasks and summaries as required. MRPM represents a facility as a tree structure. The top of the tree is the total facility. The bottom of the tree are the components and tasks. The facility is defined by attaching a unit of measure (7,200 SF) to a node (system - HVAC, subsystem - doors, component - built-up roofing in the tree). MRPM performs resource calculations by moving down the facility tree until a node with a quantity is reached. The resources are then calculated by using the quantity, basic task or summary resource data, and unit resource costs for labor and equipment. MRPM will not continue down the branch beyond the first node that has a quantity.

5. ANNUAL MAINTENANCE EXPENDITURES

The Army spends approximately 55 percent of its maintenance dollar on buildings and 23 percent on utility systems. The highest single facility expenditure area is housing which consumes 26 percent of the Army maintenance dollars. The first facility area investigated was housing since this area would produce the largest possible benefit.

6. HOUSING RESEARCH

Ten installations (6 in the United States and 4 in Germany) were selected to participate. Each installation modeled their housing facilities by forming facility groups. A typical set of as-built drawings was provided for each facility group. Each facility was modeled at the detailed component level. All costs were calculated in constant 1985 dollars. Resource calculations were performed at the task level. Two types of calculations were performed: (1) the first type was to determine the maintenance costs based upon the age of a facility. An 80-year period was selected since slate roofs had the longest component life. Calculations were performed on an individual facility basis and on a facility group basis. (2) The second type was to determine the annual costs for the period 1973 through 1992. Calculations were performed on each facility group and summarized by F4C, installation, major command, and total Army.

6.1 Labor Rates

The rates charges by the six U.S. installations varied over 50 percent within each trade. The German rates varied about 25 percent within each trade. The relationship between Germany and U.S. is also affected by a fluctuating monetary exchange rate. During the spring of 1985 the U.S. rates were almost double the German rates.

6.2 Equipment Rates

The equipment rates varied over 100 percent.

6.3 Facility Costs

The cost to maintain the identical facility with identical wear factors at each installation could vary over 70 percent due to the fluctuation of the labor and equipment rates.

6.4 Resource Information

MRPM produces the same standardized resource information for all nodes (tasks, components, subsystem, system, total facility) in the facility tree. Information is recorded by facility node number. Resources are reported by year. The following resources are recorded for each year for every task:

a. The total number of times the task was performed during this year on the facility or the total number of tasks performed below this node in the facility tree structure.

b. The total labor hours expended performing the tasks.

c. The total equivalent labor hours for materials expended performing the tasks.

d. The total equipment hours expended performing the tasks.

e. Total annual task labor costs: Labor hours multiplied by the appropriate installation shop rate.

f. Total annual task material costs: Equivalent labor hours for materials multiplied by the installation shop rate.

g. Total annual task equipment cost: Equipment hours multiplied by the appropriate equipment rate for the shop.

h. Total cost per year: Sum of the individual labor, material, and equipment costs.

i. Total cost for the report period: Sum of the total annual cost for all years in the report period.

6.5 80-Year Life Cycle Costs by Age of Facility

MRPM assumed that all tasks occurred on the average frequency; for example, the roof would be replaced every 15 years. All facilities produced a saw-toothed resource prediction. The patterns for each facility resource requirement was different. The majority of the teeth or spikes were approximately the same magnitude as the valleys or constant portion of the saw blade. Approximately 30 percent of the spikes were over 10 times the magnitude of the valleys.

6.6 80-Year Life Cycle Costs by Age of Facility Group

Most installations have many housing facilities constructed from the same set of drawings. Installations usually try to maintain groups of such facilities in the same condition. For facility group calculations, MRPM assumed that the tasks for a facility group would be evenly or uniformly spread over the frequency period between the high and low frequency. This should produce the flatest resource requirement profiles. For example, for a group of 105 facilities, if roof replacement would normally occur between the 11th and 25th years (15-year period), then 7 roofs would be replaced each year of the period. The results of all facility groups were identical in general form. A saw-toothed pattern was seen in each facility group. The magnitude of the peak values ranged between two and three times the magnitude of the valley values. None of the facility groups could be reasonably represented by a straight line.

6.7 Resource Requirements for 1973-1992

The actual resource predictions for all family housing and unaccompanied personnel housing F4C codes at each installation was calculated. The resource graphs were sinusoidal in nature with very little similarity between installations in the United States. German installations were similar due to the use of identical standard drawings and very close construction periods at each installation.

6.8 Facility Modeling Methods Tested Using MRPM

Each facility was modeled by using three different levels of detail.

a. Detailed tasks (T): All components of the facility were described. Calculations were performed by using the tasks associated with each component.

b. Gross Square Footage (S): The facility was modeled using the gross square footage. The summary resource table for the total facility was applied to perform the resource predictions.

c. Mixed Systems and Tasks (C): For systems that historically showed low expenditures in resources (plumbing, electrical, HVAC) the gross floor area was specified at the system level. Calculations were performed using the summary data. For systems that historically showed high expenditures in resources (roofs, floors, walls) the actual tasks for the components were used. Calculations were performed using the basic task data.

The three methods of modeling the facility produced resource requirements that varied between 50 and 100 percent. There were no consistent trends across the installations. The four German installations showed similar trends. The task level model exhibited a somewhat saw-toothed pattern while the two other methods showed much smoother curves. The curves were located in the same general positions. The square footage model curve was the highest; the task level model curve was the lowest; and the mixed model in between. The similarities were caused by several items. The German government applies standard designs to all family housing throughout all German bases. The construction years were comparable at the four installations. There was a wide difference in construction materials used in Germany vs. the United States (slate roofs vs. built-up roofs).

6.9 Conclusions

The following major conclusions can be made from this research into housing:

a. Resource requirements for an individual facility are not constant from year to year, nor are the requirements constantly increasing.

b. Resource requirements at the installation, major command, and Army levels are not constant from year to year.

c. In order to eliminate, or hold constant, the backlog of uncompleted maintenance requirements the Army must obtain a different level of resources each year.

7. SUMMARY

This research is not limited to Army applications. The data and programs can be used by the private sector or any other government agency to predict maintenance requirements.