Improving Software Development Project Team Performance: A Web-based Expert Support System for Project Control

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Abstract

Delivered software is often late and over budget, while offering fewer features than requested by the user. Many software developers have difficulties establishing and adhering to a project plan and in delivering what the user wants within the budget and schedule. Developers also have difficulty in obtaining user involvement in the development process. This paper discusses a Web-enabled expert system, Project Management Advisor (PMA), which will provide alerts and corrective actions for some of the common problems that plague software development projects. PMA was developed as a part of a CyberCollaboratory built to facilitate collaborative project work. The development and evaluation of a collaborative generic expert system for identification and analysis of anomalies in project plan data is expected to be useful to many software development teams and managers in a wide variety of organizations. PMA is a field prototype and was evaluated using 11 real world project plans. The preliminary analysis of the findings is presented and discussed.

1.0. Introduction

> So far as the laws of mathematics refer to reality, they are not certain. And so far as they are certain they do not refer to reality.
>
> Albert Einstein

For software development projects Einstein's words were prophetic. Project managers use mathematical tools to help manage projects but these tools are unable to deal with the uncertainty of incomplete or changing user requirements, lack of user involvement, and inexperienced project managers.

One of the largest problems facing management today is the management of software development. It is estimated that over 1/3 of all software development projects, upwards of 80 billion dollars each year, are abandoned before completion. This problem spans corporate and national boundaries. Only 18% of completed software projects are within budget or on time [21] [10] [22] [16].

Some of the root causes are: incomplete and/or creeping user requirements, lack of user involvement, and inexperienced or poorly trained project managers [2] [10]. Other causes are system's scopes that are too large or too visionary, and incomplete testing [14]. These factors all increase the risk associated with a software development project and the probability of failure.

For a project to succeed a well-defined project plan is essential [5] [16] [1]. However, user involvement coupled with well-defined requirements and small deliverable milestones are also necessary.

Today's stand-alone project management tools do not address the root causes mentioned above. Project management systems such as these focus on schedule variance using historical data as the basis for analysis [1]. Traditional project management tools are based on a rational model of decision making, are quantitative, and work relatively well for structured and semi-structured decision-making [9]. They do not perform the less structured decision analyses such as whether enough testing has been conducted or whether user involvement is adequate. Neither are these systems designed to issue alerts to *potential* problems, provide assistance in the analysis of project plans based on heuristics or expert judgement, or assess risk [10] [2]. These are some of the gray areas we hope to address with our expert system, PMA.

The next section presents the theoretical framework for PMA. Section 3 describes the architecture of PMA. Section 4 discusses the methodology employed for the knowledge engineering process. Section 5 presents the expected advantages of PMA. Section 6 demonstrates the PMA system, section 7 presents preliminary field study findings, and section 8 discusses conclusions and future directions.

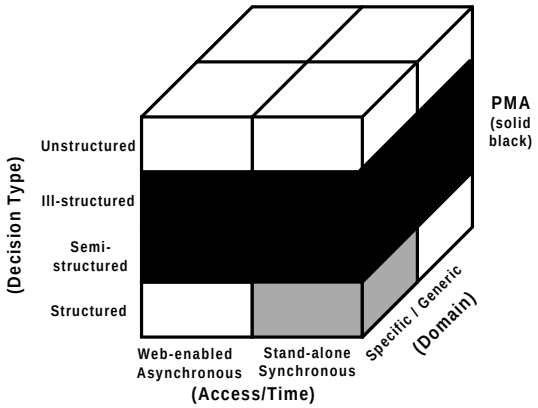
2.0. Theoretical Framework

Figure 1 shows our conceptual framework for a web-enabled generic expert support system. This framework was developed by incorporating three conceptual models:

a Generic Expert System [13], an Expert Support System [9], and an Asynchronous CyberCollaboratory [7].

PMA is flexible, robust, and easy to use. It is designed to address all three of the dimensions in the conceptual framework except unstructured or strategic type decisions as shown in Figure 1 (solid black area). Traditional project management systems are domain specific and address only well-structured problems as shown in Figure 1 (striped area).

Figure 1. Conceptual Framework for Web-enabled Generic ESS

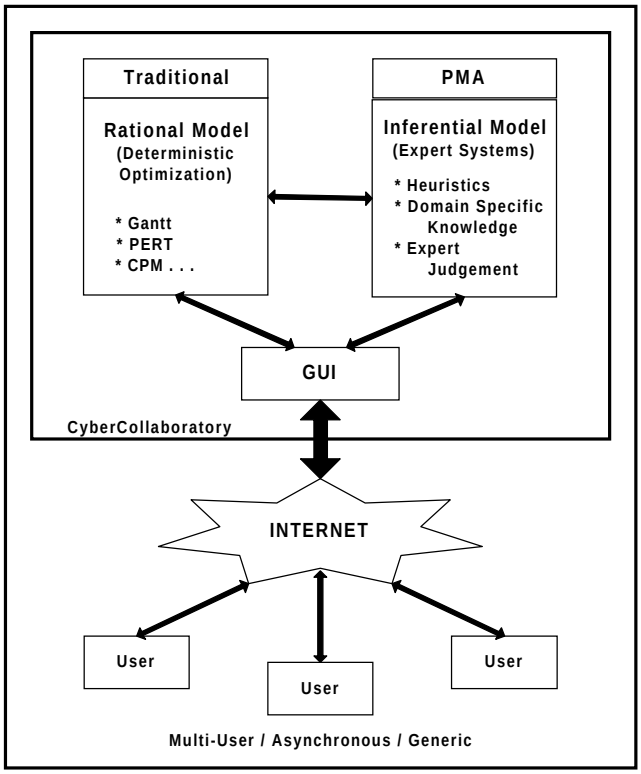


The commercial project management tools in use today have several major deficiencies. They are based on the deterministic optimization techniques and do not issue warnings regarding possible future schedule slippage, analyze the causes of delays, or provide recommendations for remedial action. Some planning systems have incorporated historical data from completed projects to use as the basis for planning [8]. However, these methods still lack the predictive value of an expert system, which has the thinking processes of an expert project manager, embedded within its knowledge base. Nor do these traditional systems facilitate team collaboration or user involvement.

PMA is a major extension of the traditional model as shown in Figure 2. PMA is Web-enabled, generic, intelligent, and embedded within a CyberCollaboratory [7]. Traditional project control systems are based on a rational decision process using either deterministic optimization or stochastic methods such as Gantt charts, PERT, CPM, GERT, and VERT [11] [15]. PMA is based on an inferential model using both human expert judgement and the database from a traditional tool to create new knowledge [9].

The underlying processes consist of building a project plan using MS-Project, and then analyzing the plan using PMA, which posts alerts and recommendations for remedial actions to the web for viewing and consideration by the project team. Corrective actions can then be applied to the project plan such as including missing dependencies. This process can be conducted in an iterative fashion.

Figure 2. PMA Conceptual Framework



3.0. PMA Architecture

The PMA architecture is shown in Figure 3. PMA is being developed as part of a suite of asynchronous software team technologies we refer to as the CyberCollaboratory [7]. Our objective in developing PMA for inclusion in the CyberCollaboratory is to provide an intelligent, asynchronous, multi-user [24] project management environment for teaching and learning.

The CyberCollaboratory software is comprised of Domino 4.6 and Lotus Notes (the groupware), and software tools such as the PMA extension to project management. Also included are group decision support system (GDSS) tools such as voting, idea organizing and electronic brainstorming; Discussion Groups; Real-time Chat; and CASE tools [7].

4.0. Methodology

We followed a typical knowledge engineering process, which includes knowledge acquisition, knowledge representation, system development, and

testing and validation [23]. Each of these steps is discussed in detail in sections 4.1 through 4.4 below.

4.1. Knowledge Acquisition for PMA

Two experts with combined experience in project management of more than 30 years participated in compiling the PMA knowledge base. Their experience includes project management in software development, construction, and telecommunications. Their domain specific knowledge, heuristics, and expert judgement in project management were collected through cyber meetings and face-to-face interviews over a one-year period.

It was determined that incomplete project plans, lack of user input, incomplete requirements and specifications, and changing specifications and requirements or scope creep are often the source of project problems [2] [17] [18]. Experienced project managers often know how much user involvement is enough and when to involve the user in the development lifecycle. More experienced managers also know when the project scope is creeping and how to nail down requirements through the use of success criteria, prototyping or the phasing of requirements. Inexperienced project managers often do not. PMA can be used by inexperienced project managers to deal with these kinds of problems.

PMA is designed to alert the project manager to potential problems, which typically tend to increase the risk of project failure. Unrealistic estimations of task requirements such as using a workday duration longer than 6.5 hours or forgetting to include vacations or days for illness are some examples. PMA is also designed to evaluate a project plan for anomalies both initially when the plan is established and on an ongoing basis throughout the project life cycle.

PMA embedded within a CyberCollaboratory is expected to facilitate more user involvement because access to plans and discussion groups is asynchronous. Scheduling and attending meetings will pose less of a problem when PMA is used with the CyberCollaboratory for project planning. The user will need to attend fewer face-to-face meetings.

4.2. Knowledge Representation

PMA is a rule-based expert system [20] designed to help make project managers, organizational executives, and users aware of potential problems such as scope creep, project plan problems, inadequate user involvement, and inadequate testing. One of the PMA rules in English is shown in Figure 4.

4.3. System Development

As shown previously in Figures 2 and 3, users can access PMA through the Internet with any type of Web-browser from any place, at any time. PMA was initially developed with an expert system shell, EXSYS-PRO, to validate the concept. It was reprogrammed with LotusScript with agents due to web access issues, integration with MS Project, and performance. PMA in LotusScript with agents works very well with a MS Project database in MS Access format.

Lotus Notes provides access to various tools including PMA, Group Decision Support System (GDSS) tools, Discussion Groups, Real-time Chat, and CASE tools. Lotus Notes Script Language is used to launch PMA and other tools and to access the external database (MS-Access database extracted from MS-Project) for PMA analysis. Lotus Domino makes Lotus Notes web-accessible.

Figure 4. A Sample Rule of PMA

```
RULE NUMBER 11  Excessive Workday
{IF     Dependency_Check is OK
 AND    Workday is more than 7 hours
 THEN   Excessive_Workday is YES
 DO     Add the resource to Excessive_Workday List
}
```

4.4. Testing and Validation

PMA was developed as a field prototype [9]. Testing was conducted using a medium sized project plan modeled on a real world marketing systems project plan that contained approximately 600 tasks and all of the phases of a standard lifecycle model [3]. PMA was validated by the industry experts who participated in the knowledge acquisition process. The results show a clear ability to identify project plan anomalies such as tasks that are too long, tasks that should have dependencies, lack of user involvement, and inappropriate scheduling such as using an 8 hour workday. PMA also provides explanations and suggested corrective actions.

After testing, PMA was evaluated using 11 real world project plans. The preliminary analysis of the findings is presented and discussed in section 7.

5.0. Advantages of PMA

PMA is expected to provide:

1. guidance and direction in correcting project plans for students and novice users;
2. assistance for project managers in the field to improve project control by identifying project plan anomalies and recommending remedial actions; and
3. senior managers with the ability to look at an objective expert evaluation of a project plan.

The expert judgment embedded within PMA can be used to flag potential problems and offer remedies to those problems. A high level of proficiency and experience are required to develop workable project plans and to deliver software on time within the budget [16]. The expert guidance provided through PMA is expected to improve over all project management outcomes. The collaboration facilities are expected to increase user involvement and therefore user satisfaction.

PMA is generic in the sense that can be applied to a wide variety of software development projects. PMA is designed to work with the database of a deterministic optimization project planning system such as Microsoft Project and is expected to have wide applicability across organizations. Our initial goal was to provide an asynchronous collaborative environment to teach project management skills to students in our MIS program. We made PMA generic because our students are from diverse backgrounds and are working on software development projects from a wide variety of industries and government agencies.

PMA is Web-enabled. The decision to make PMA Web-enabled was a result of the frustration we observed in industry where users or executives want information about a project's genuine status (generally after some major milestone is missed), but are unable to obtain such information. The analysis can be conducted by anyone having a PC and Web access. Developers frequently report tasks as being 95% complete. In reality the work remaining on a task is more likely to be substantially more than 5%. This phenomenon is similar to covering half of the distance to the doorway.

Whether developers are reluctant to share accurate information or simply do not have accurate information is not relevant. In either case access to PMA is expected to be helpful in disseminating information to users, developers, and management.

Web-accessibility also encourages more user involvement. Individuals who have been granted access permission, and have a standard web browser and web access can easily look at the PMA project analysis and make comments or suggest modifications.

6.0. PMA Interface and Navigation

The PMA expert system analysis can be grouped into five categories. These are; the Initial Project Setup, Ongoing Project plan analysis, Risk Analysis, Earned Value Analysis, and, User Involvement Level analysis as shown in Figure 5.

6.1. Project initial setup and PMA analysis

After the project has been defined and the project plan has been established, a preliminary analysis of the project data can be conducted. The preliminary analysis includes analysis of dependencies, schedule feasibility, resource feasibility, slack time feasibility, and large deliverables as shown in Table 1. Some of the alert types for the ongoing project analysis are shown in Table 2.

Table 1. Preliminary Project Plan Analysis (Selected topics)

Dependency analysis (i.e. are dependencies incorrect or missing, and do any tasks have locked in end dates).
Schedule framework feasibility (i.e. have vacation days, holidays, or overtime been included in the project plan).
Resource scheduling feasibility (i.e. have resources been assigned to all project tasks and appropriately scheduled).
Slack time feasibility (i.e. are tasks with no slack time items that could place the deliverable in danger)
Large deliverables: Tasks that are scheduled to take more than 40 hours (5 days) to complete will be identified and broken down into sub-units.

Table 2. Ongoing Project Plan Analysis (selected topics)

Alerts That May Indicate Project Slippage or Scope Creep
• The project plan has no baseline or the baseline has been modified.
• The project end date has changed.
• The total effort for the project has changed.
• Tasks have been added or deleted from the schedule.
• Estimated effort (total or remaining) has changed (increased).

When the Initial Project Analysis option is selected, the menu screen for the Initial Analysis is displayed as shown in Figure 6. Users can select from the five options which are: task analysis for tasks without dependencies, task analysis for tasks with dependencies, work duration analysis, project vacation analysis, and task resource analysis.

For example, when the task analysis option is selected, PMA examines the selected project database for potential anomalies and problems. PMA then generates a report, an explanation of findings, and recommendations for corrective actions as shown in Figure 7. Another example of the Initial Analysis, Workday Duration Analysis, is shown in the Figure 8, which contains the explanation of findings and suggested remedial action. Figure 9 shows the Ongoing Analysis menu.

A senior manager might wish to simply view the project alerts and use these to open a dialog with developers. On the other hand, a student or a project manager would use the explanation and remedies to improve the quality of the project plan [12].

7.0. Preliminary Field Study Finding

We analyzed 11 real world software development project plans. The details are presented in tables 3 and 4. Projects ranging from relatively small (22 tasks) to large (557 tasks) were evaluated. PMA found that for seven of the eleven projects more than 75% of the tasks had no assigned dependencies. On average, the PMA analysis of the 11 project plans showed that more than 70% of the tasks did not have any assigned dependencies.

None of the plans considered vacation time or potential sick-days. All eleven used an eight-hour workday, which means the project may be unrealistically under estimated. Four of eleven plans had no resources assigned to tasks at all. On average, PMA predicted that even the seven projects having assigned resources were in jeopardy of being at least a month late.

These findings could be interpreted in two ways: 1) project managers are not using the traditional planning tool properly; or 2) project managers are not trained to use the traditional planning tool properly. We expect that PMA may be able to improve project management skills significantly by providing continuous training and tracking.

8.0. Conclusions and Future Directions

As more companies invest time and resources in project management in an effort to contain software development costs, tools such as PMA are needed. Expert system based project planning and control tools are flexible and they bootstrap themselves by learning. It is clear that new tools are needed both for project management and to facilitate user involvement [11].

In addition to the replication of expertise, the knowledge of several experts can be incorporated into a single knowledge base [12]. These group knowledge bases provide the experience needed by new or inexperienced project managers to create and adhere to a well-defined project plan.

Other tools such as the more rigid deterministic optimization tools that are the basis of most project management software fail because more flexibility in the form of heuristics and expert judgement is needed [19]. Managers often lack either the experience or the training to do adequate project planning and control. PMA can be used to augment the project manager's judgement.

In the near future PMA's generic applicability will be tested further using more "real world" plans from a variety of corporations. Since PMA is Web-enabled and can be used to analyze project plan data from any Microsoft Project database we expect PMA's performance to be consistent across organizations. At UIS, PMA will be incorporated into our MIS curriculum for student training in project management techniques. The educational outcomes will be evaluated and presented in future papers.

The research questions we wish to investigate relate to software development and delivery and the development and deployment of tools that will help managers correct project problems before they cause significant delays; tools that provide an early warning system if you will. We also plan to compare the outcomes of projects where PMA is used to assist in project management and control to projects where a traditional project-planning tool is used.

Many important research questions remained to be addressed through the study of PMA as used by our students. Some of the research questions are:

- Is it possible to use PMA to reduce the discrepancy between the planned estimates and the actual project outcomes?
- Can a learning loop be established to improve the accuracy of a project plan?
- Can use of PMA change social attitudes and negative biases toward obtaining accurate project estimates [25]?
- Will PMA encourage more user involvement in project planning?

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Keywords: Project Management, Web-enabled Project Control System, Software Engineering, Expert Support System, Generic Expert System, Collaborative Planning and Scheduling, and Collaborative Team work.

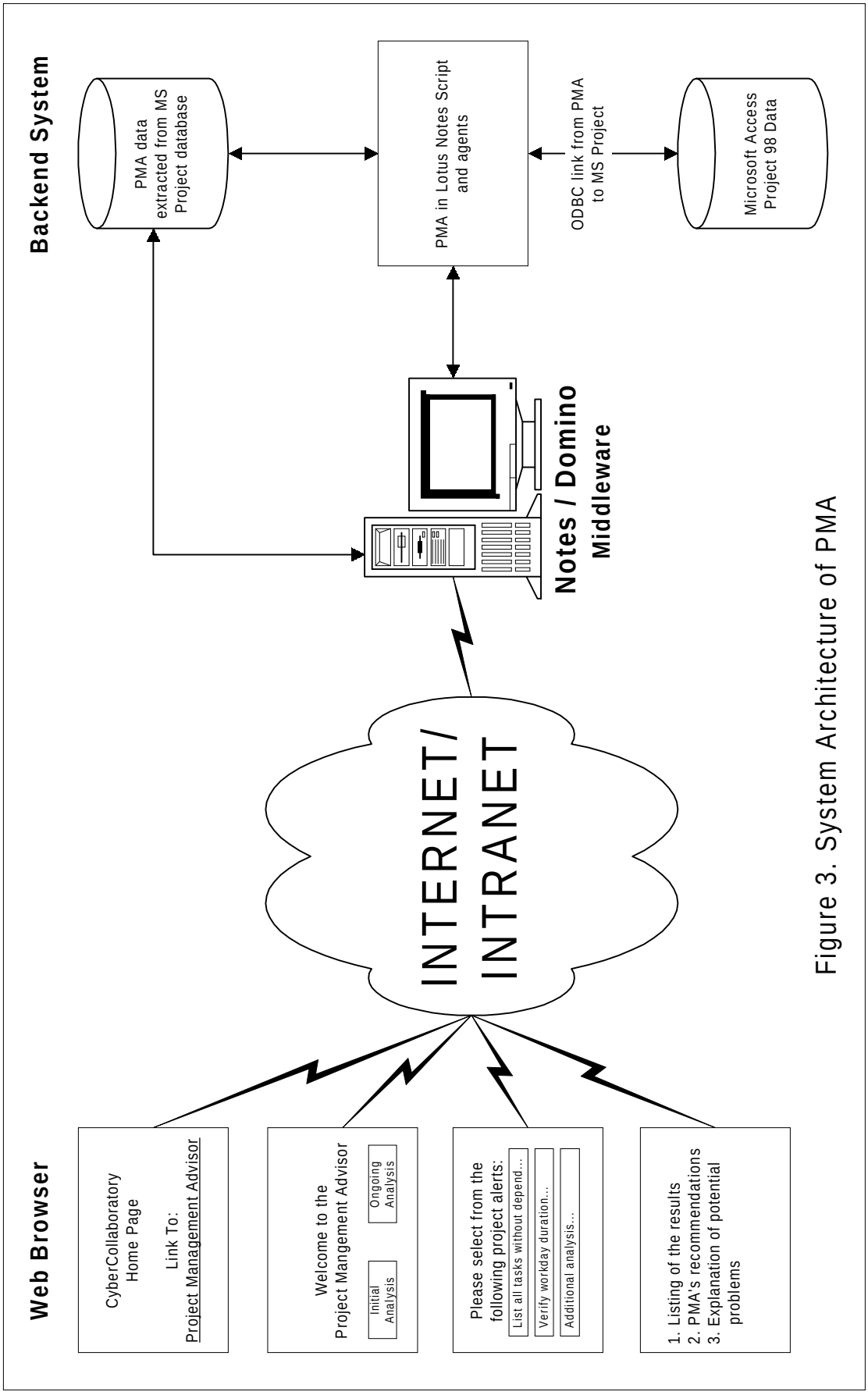

Figure 3. System Architecture of PMA

Figure 5. Project Management Advisor (PMA) Interface

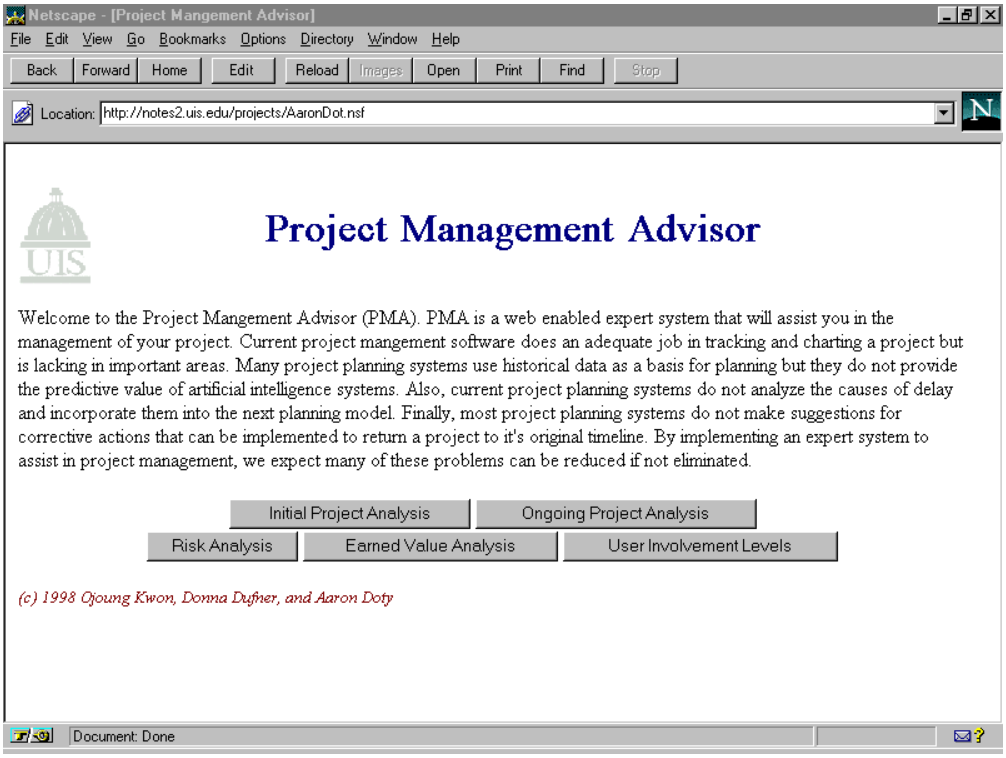

Figure 6. PMA Menu Screen for Initial Analysis

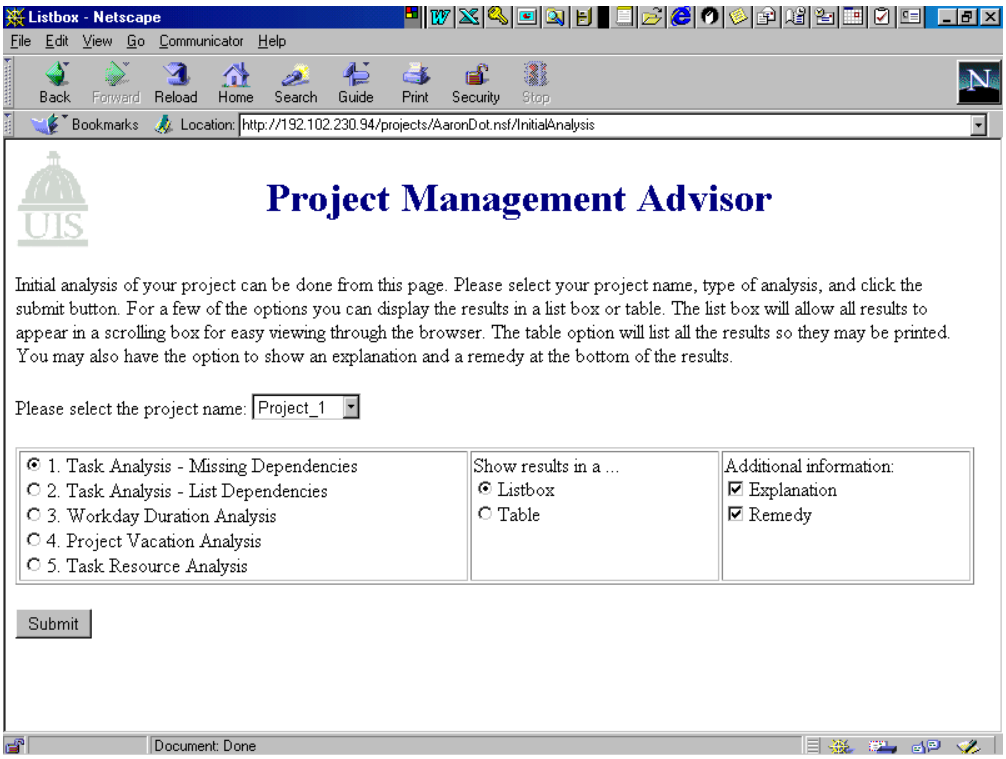

Figure 7. Report Showing Tasks with No Dependencies and PMA's Recommended Actions

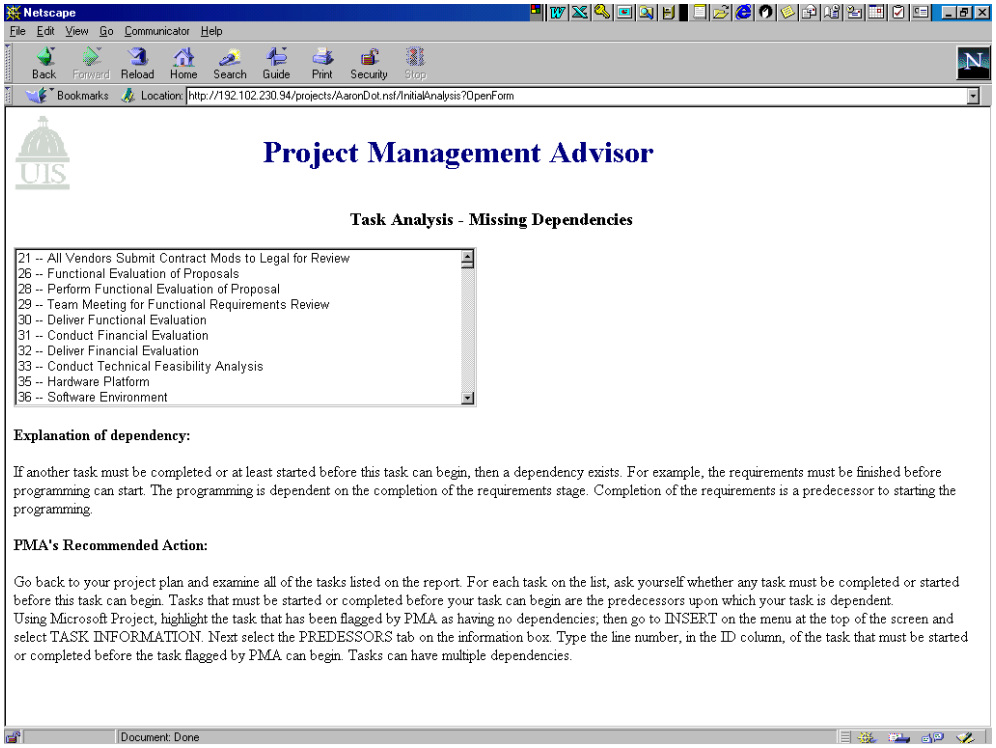

Figure 8. PMA Alert for an Unrealistic Work Schedule

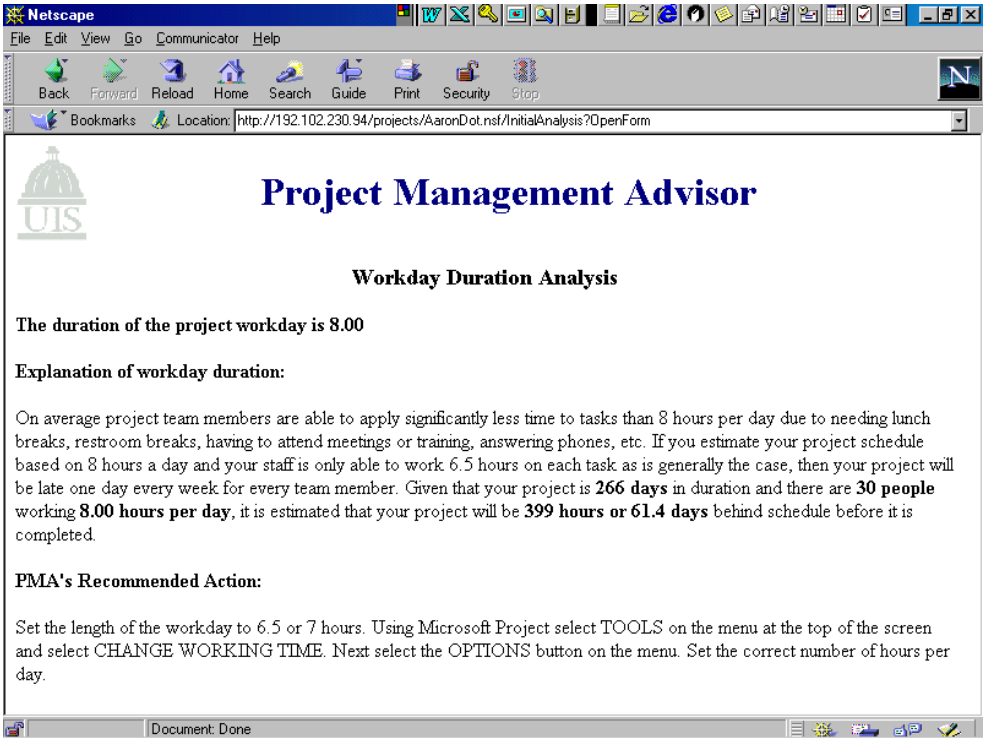

Figure 9. PMA Menu Screen for Ongoing Analysis

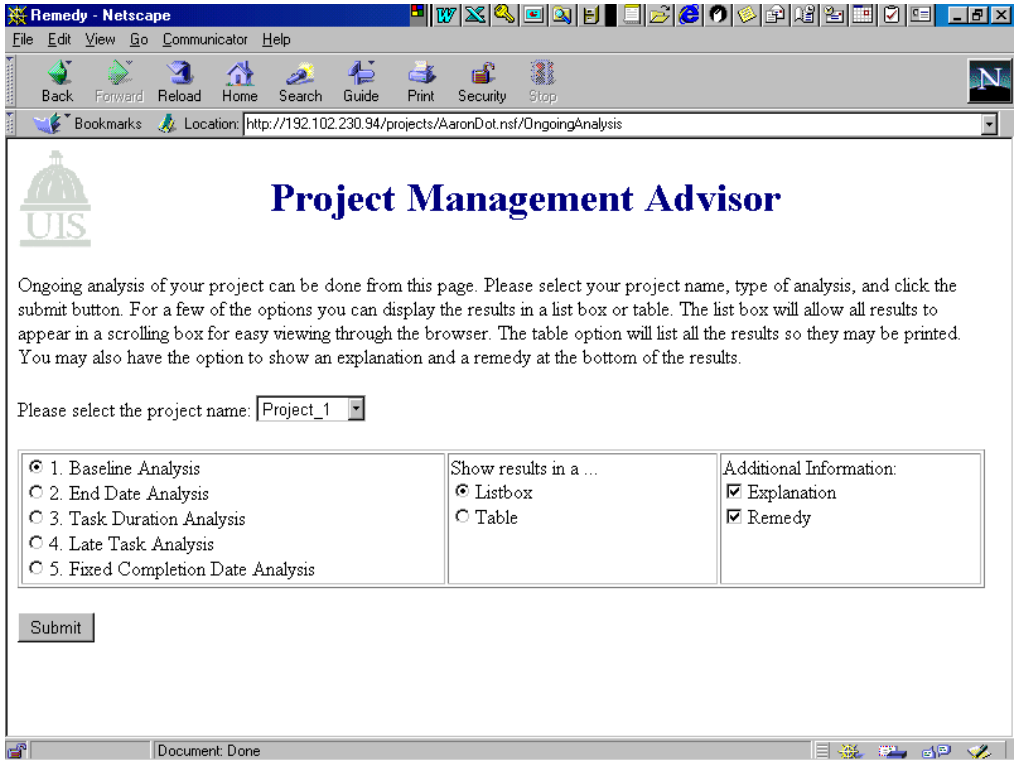

Table 3. Results of the Initial Analysis for Missing Dependencies

Project (n=11)	Missing[1] Dependencies	Dep.[2]	Total	Missing (%)
1	179	5	184	97.3%
2	0	87	87	0.0%
3	4	79	83	4.8%
4	139	0	139	100.0%
5	431	126	557	77.4%
6	121	109	230	52.6%
7	412	0	412	100.0%
8	137	0	137	100.0%
9	192	0	192	100.0%
10	22	0	22	100.0%
11	27	40	67	40.3%
Total	1664	446	2110	772.4%
Average	**151.3**	**40.5**	**191.8**	**70.2%**

1. Tasks with no assigned dependencies
2. Tasks with assigned dependencies

Table 4. Results of the Initial Analysis for Workday Duration Analysis

Projects (n=7)*	Duration	Resource (people)	Hours	Days
1	94	1	141.0	21.7
2	76	4	114.0	17.5
3	71	6	106.5	16.4
5	266	30	399.0	61.4
6	71	15	106.5	16.4
10	38	1	57.0	8.8
11	226	27	339.0	52.2
Total	842	84	1263.0	194.4
Average	**120.3**	**12.0**	**180.4**	**27.8**

* denotes 4 projects did not have any resources assigned.