Intelligent Project Management and Automation Systems

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***Abstract*— Effective management of projects is becoming increasingly important for any type of organisation to remain competitive in today's dynamic business environment due to pressure of globalisation. Planning a project with proper considerations of all necessary factors and managing a project to ensure its successful implementation are facing a lot challenges. Initial stage in planning a project is costly, time consuming and usually with poor accuracy on cost and effort predictions. On the other hand, detailed information for previous projects may be buried in piles of archived documents, which make it increasingly difficult to learn from the previous experiences. Project portfolio has been brought into this field aiming to improve the information sharing and management among different projects. However, the amount of information that could be shared is still limited to generic information. In this paper, we design and implement a novel software system iPAS, which automatically generate a project plan with effort estimation of time and cost based on data collected from previous completed projects in standardised industries. To maximise the data sharing and management among different projects, a method of using product-based planning from PRINCE2 methodology is proposed. iPAS has been trialed with cases in two organisations, which clearly shows the business benefits of autonomic project management. It reduced effort to plan new projects and manage project portfolio and decreased estimation bias thereby reducing operational risk. It also automatically benchmarked performance against company best practices.**

Keywords-autonomatic project management; product-based planning; best practice; PRINCE2.

I. INTRODUCTION

In recent years, many engineering companies have spent a great deal of time bidding for Whole Life Cycle (WLC) projects from clients [1]. Most of the project planning and associated cost are developed almost from scratch, even when elements of projects are similar to those bid for in the past. Since the bidding proposal must be built around a sound and well-thought-out estimated project plan, which addresses the cost, time spent and quality to generate the final product to be responsive to clients' delivery requirements, it will take considerable time and therefore incurs resource costs, which could be a big cost saving.

Frequently, the best practice of assessing through life support resources in the engineering services sector is to benchmark against a similar and previous project [3] by using historical data. Best practice is defined as the most efficient (least amount of effort) and effective (best results) way of accomplishing a task or a deliverable, based on repeatable procedures that have proven themselves over time for large numbers of people [2]. Benchmarking is considered as a technique to provide a systematic approach to improving business production efficiency and profitability through comparing and analysing the values from varying resources. Thus, benchmarking and utilising best project practice are the key issues for enterprises to persist in contract competition and project planning.

Currently, most best project practices are made explicit in terms of persistent data from operational processes or activities, but underlying influencing factors remain implicit. The risk of such practice is the cost estimation will not take into account other factors, such as different environment, technology advances and different customer profiles [3].

On the other hand, main stream project management methods nowadays are process or activity based. Therefore, the granularity of information is collected merely at the activity level. Project portfolios which assist the decision makers on corporate strategy and project management practices are also mainly represented based on process. Project information sharing happens only at the activity level, or at the project level, in this case. At activity level, information is not easily sharable due to the fact that new technologies, process re-engineering and different personnel preferences may all affect the practices of conducting project activities. The vast amount of information in between which contains the best practices of working on certain products (deliverables) is not even collected. There is an emerging requirement from industries to have a tool to use good practices or lessons learned from previous projects to guide the new projects.

This paper introduces a web based adaptive project information sharing and management system - iPAS (Intelligent Project Automation Systems). iPAS is developed by following modern software engineering methodologies, PRINCE2 [4] principles and the practical experience of project managers. iPAS consists of four main project management functions: project planning, progress monitoring, project reports and human resource allocation. It was designed for managing engineering projects, but its principles could also be applied to other project disciplines.

The rest of the paper is organized as follows. Section 2 introduces the state of the art of current project management systems. Section 3 presents the overview of the iPAS system and related PRINCE2 techniques, followed by introducing the major functions of iPAS in Section 4. Section 5 provides

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evaluation results of the system. The final section concludes the whole paper.

II. PROJECT MANAGEMENT SYSTEMS IN THE MARKET

A number of commercial tools have been created for project information sharing and project management. These commercial applications have been adopted by industry at a remarkable rate. For example, Microsoft Project [16] is able to develop project plans with Gantt charts [17], assigning resources to tasks and tracking progress; MindManager [5] can easily convert brainstorm maps into process diagrams, create standard templates so every project has continuity and can easily be exported to the Microsoft Office suite; @TASK [6] has features such as interactive Gantt charts, calendar views and project group lists that are designed to minimise downtime and make data management easy; ASTA Power Project [7] is a standalone software to do the time planning, project progress monitoring and resource management; Instant Business Network (IBN) Project Management [8] provides a cost-effective and flexible approach to repeating success and re-using a unified system to consolidate corporate information into a single web portal.

However, the most widely used project management features of these applications are fairly conventional. For instance, the classical feature of graphical plan and critical path analysis, display the Gantt chart view by default encourages users to focus on task or activity scheduling too early, rather than identifying objectives and deliverables. Moreover, plans generated by these applications are based on activities, which make it difficult to perform the benchmark because different project users may have different approaches to deliver the same product. The detailed information collected at the activity level can be useful for future project planning only when the same work practices are followed. In addition, due to no shared central database to store historical data, these project management applications cannot do benchmarking from previous projects and use the historical data to produce an automated project plan.

III. IPAS SYSTEM

As mentioned previously, many engineering companies spent considerable time bidding for projects by developing project plans from scratch. It also means that bids are not always consistent and sometimes contain inaccuracies, which can be costly if the project is won and the cost profile is proved to be wrong. Furthermore, on contract award it is difficult to substantiate existing data on project success to improve customer confidence.

Although benchmarking has been brought into project management, the risk is the effort estimation will not take into account other factors, such a different environment, technology advances and different user profiles. Companies, such as Dytecna [1] have previously been financially penalised by poor benchmarking techniques. Dytecna is an engineering company providing engineering service solutions for governments and commercial customers, both in the United Kingdom and overseas. Its core business activities include Systems Engineering, Whole Life Support, Manufacturing, and Asset Management/Health Monitoring Systems. A research project was proposed by Dytecna a couple of years ago to employ benchmarking techniques to improve current information sharing and management of the whole life cycle of projects based on the best practices from historical data, and find a method to analyse the completed and existing projects to convert Activity Based project information into Product Based information. The outcome of the project is an adaptive project information sharing and management system – iPAS which is based upon the principles of the best practices and the methodologies from PRINCE2 to manage the whole lifecycle of project.

A. iPAS Overview

The philosophy behind the design of iPAS is to facilitate system learning from previous projects in light of benchmarking criteria and present to the project manager a manageable amount of easily-derived information organised to give insight, information, or alerts about project status.

To achieve this goal, iPAS is designed to intelligently assist with the through life management of projects based on best practice and experience from previous project profiles. The system is expected to automatically deliver project plans to match customer requirements and provides a mechanism for continuous monitoring of project execution via benchmarking and generation of project reports.

In order to fully utilise this service, an additional consultancy service package is provided to help customers to break down their products into sub-products or work packages in accordance with PRINCE2 project management principles such as Product Based Structure and Product Flow Diagram. This data is stored in a central database for analysis and benchmarking enabling project managers to control their projects with greater precision. Thus, iPAS system consists of two main parts: a web based project management tool which allows users to access it anytime and anywhere, and a consultancy service (shown in Figure 1).

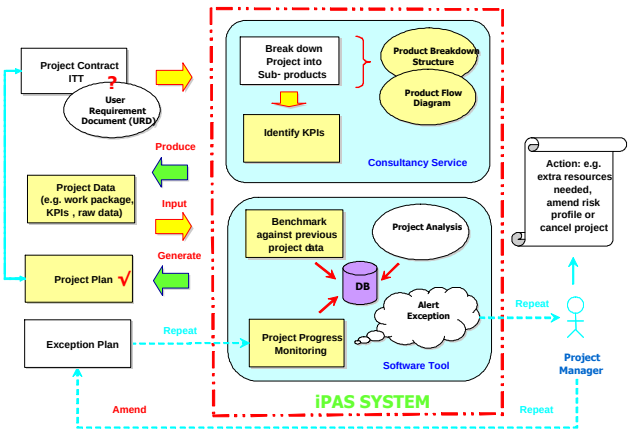

Figure 1. iPAS Overview.

When a company receives Invitation To Tender (ITT) to submit a project bidding, the user requirement document will be used as an input of the consultancy service part of the system. With the help from project management domain

experts, the project will be broken into sub-products by using Product Breakdown Structure (PBS) [4] and Product Flow Diagram (PFD) [4] techniques, relevant project data such as work packages and identified Key Performance Indicators (KPIs) will be produced as an output of the consultancy service part.

These raw project data then will be stored into iPAS software too. This tool will automatically analyse and provide forecasts for newly entered ITT data, by benchmarking it with historical project data. The tool is able to produce accurate plans through analysis of entered criteria against benchmarked data, which helps project managers to decide the project plan. If the bidding is successful and when the new project starts, the tool will also monitor the project plan by measuring identified key performance indicators (e.g., time, cost and quality) in produced work packages during the project life cycle. The project management team will receive alerts if any project activity goes wrong or beyond the controls during the project progress. Immediate action can be taken, such as allocate extra resources when needed or amend the risk profile, or even cancel the project, to ensure the project status is healthy. A final report can then be generated to summarise the project. Benchmarked data will be updated in a central database at the end of the project to improve the analysis provided to subsequent projects or biddings.

B. Product Based Planning Technique

Project planning is about effort estimation including time, cost and resources, which is based on expert judgment and analogy using historical data from completed projects. Consistency in historical data gathering is the key to reliable estimates [9][10]. Especially data for status report in business project management system should be collected during and after project, but in rare cases automatic data capture may be available [11].

iPAS uses product breakdown structure to delineate the project scope and define a list of deliverable products to be constructed during the project. The products must be identified before the activities are defined since the object of the project is to produce deliverables. As mentioned in last section, in accordance with PRINCE2 project management principles, users need to break down projects into work package sized products (includes intermediate documentary products and final end-products) before fully utilising iPAS. Therefore, it is expected that products (or work packages) are identified through PBS and PFD before using iPAS tool.

Compared to activity-based planning or process-based planning, a significant advantage of product based planning is to do with reporting. It can more precisely control the scope of the project and focus only on what is really needed to meet the business case. Products are either finished or not, activities can be 95% finished for a long time even though work is taking place [12]. One tends to forget things that have to be done to complete a project. This method captures them all, reducing the chance that any will be overlooked. Another significant advantage of it is that it will be much easier to benchmark with same or similar products because different project users may have different processes or approaches to delivering the same product, but the properties (e.g., quality, cost and time) used to measure the completed product should be the same.

Here is an example of project plan to integrate current IT operations into a "Web Based Information Management System (WBIMS)" in Dytecna Ltd. In PRINCE2, the top level of products is known as "project products". For WBIMS project, these are subdivided into three main categories, as shown in Figure 2 represented with diamond shape.

Management products are those products associated with the planning and control of the project. They include Project Initiation Documents (PID), project plan, checkpoint reports and so on. Quality products are separated from Management products, they are associated with the definition and control of quality, quality plan, product descriptions, quality review reports, and project issues report. Specialist products are those things that the project has been setup to create. It can be broken down into other three sub categories [4]:

- Analysis Products.
- Development Products and
- Implementation Products

Each category respectively includes a few products underneath. For example, Website is a deliverable of Development Products Group during the system design and development stage, while the Tested system and Implemented system (signed off acceptance system) are the deliverables of the Implementation Products Group in the implementation stage.

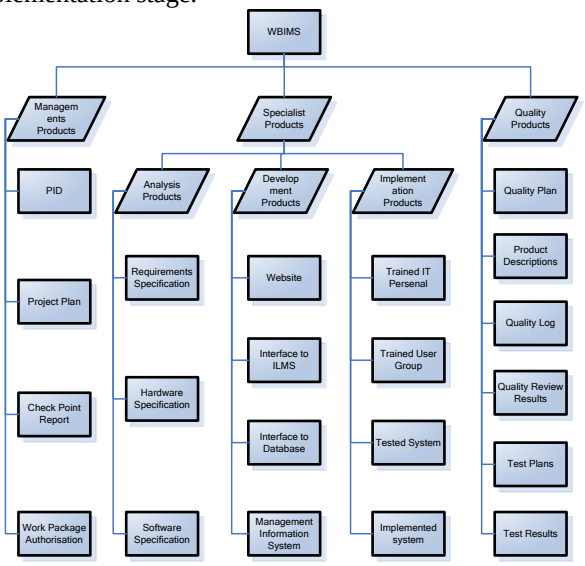

Figure 2. Product Breakdown Structure.

At the bottom level, the individual product is represented by a rectangle shape. A project product is broken down further into one or several activities. The estimate of each activity is derived based on human judgment from the product estimate and the relative complexity of each activity. Again, the total estimated effort for the activities of a product should be equal to the product estimated effort.

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Once the PBS is completed, a complete list of the products in that project will be generated. It is time to consider the work of creating a PFD. The principle is that the products in the relation to each other will be looked at and considered how one product is transformed into another. Each product may be consisting of one or more activities. Thus, the activities implied in the delivery of each of the products and those required to create or change the planned products need to be identified to give a fuller picture of the plan's workload. Figure 3 is an illustration of adding the activities and dependencies based on the PBS of WBIMS.

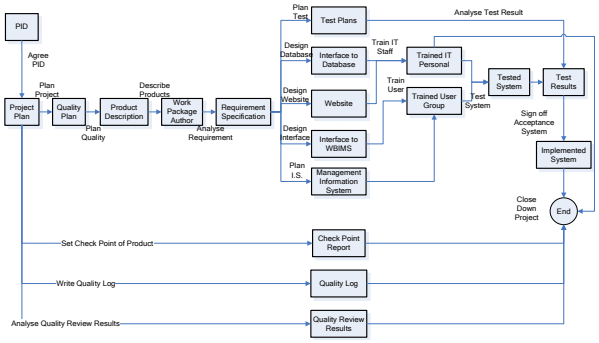

Figure 3. Project Flow Diagram.

Furthermore, the basic configuration of the system requires the entry of top level information about the project such as project category, project timeline, work package description, tolerance level, customer, etc.

C. Product-Based Project Portfolio

A product-based project portfolio (PBPP), as shown in Table I, was proposed in this research to contain more detailed information of each product apart from time, cost, resource and dependencies, such as quality criteria, constrains and activities underneath.

TABLE I. PROJECT PORTFOLIOS

	Product based project portfolio
1	Product name and description
2	Duration of completion
3	Man power
4	Cost including labour & material
5	Dependences & pre-requisites
6	Activities undertaken of each product include details of rework
7	Quality assessment criteria
8	Special technical requirements
9	Constrains & inheritable risks

The PBPP is a top level methodology to use the product-based approach for portfolio collection, project planning and project delivery. It details processes starting from product breakdown until the resource arrangements during the planning stage. The input of PBPP is from information collected from all completed projects and the output is to the new projects. The data repository of PBPP contains both project and simple product data. When a project manager plans a new project, the first step is to break the project into simple products by using PBS and PFD, then PBPP will be looked at and the portfolio of previous projects and simple products can be accessed to see whether those products have been done before. As long as the simple products are found as the same or similar, the benchmarking principle can be employed to choose a suitable product. The activities associated with the chosen product will be regarded as the most suitable practices to deliver the product in the new project plan.

Sometimes project managers need to estimate the time and cost according to their experience when there is no information found from the system. Actual information collected during the project delivery can be stored into the PBPP system again to cross check the accuracy of the previous planning to improve the calculation method for future references.

The PBPP has the obvious advantages to allow maximum information and best practice sharing among projects at the product level. It overcomes the limitation of traditional activity based methods when sharing information at the activity level.

D. Product Portfolio Benchmarking - Automomous Process

After breaking the final product into sub-products, the next step is to benchmark the sub-products to find the best practice among the historic data for project planning. The Quartile approach [14] was applied here to enhance the benchmark process. It shows the spread of the most popular representatives for non-numerical data. This concept refers to the subset of all data values in each of those parts.

TABLE II. QUARTILE LEVELS

User Requirement			
Time (Prior)		**Cost**	
Quartile	**Criteria**	**Quartile**	**Criteria**
Maximum	1	Maximum	**1**
Upper Quartile	**0.75**	Upper Quartile	0.75
Medium	0.5	Medium	0.5
Lower Quartile	0.25	Lower Quartile	0.25
Minimum	0	Minimum	0

In terms of the user requirements, the WBIMS project delivery time is crucial to the customer, for this reason, the project completion date was fixed; thus, the project time chosen as the higher Build Priority of the project when using iPAS software. In other words, the project completion Time is prior to Cost during the benchmarking process, the Criteria Expectation of project completion Time was set as Upper Quartile and project completion Cost was set as Maximum (see Table Π) when configuring the project settings in iPAS (Figure 4), which means all the sub-products in WBIMS project will be benchmarked by following steps:

1) the top 25% products of all products in data repository that have a fairly good completion time will be selected firstly,

2) these selected products will be put into the second round selection to meet the lower prior criteria - the selected

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product must have the lowest cost among those completed products,

3) the product that meets both criteria on Time and Cost will be regarded as the best practice, the completion Time and spent Cost as well as all activities that came with this product will be used for generating a new project plan.

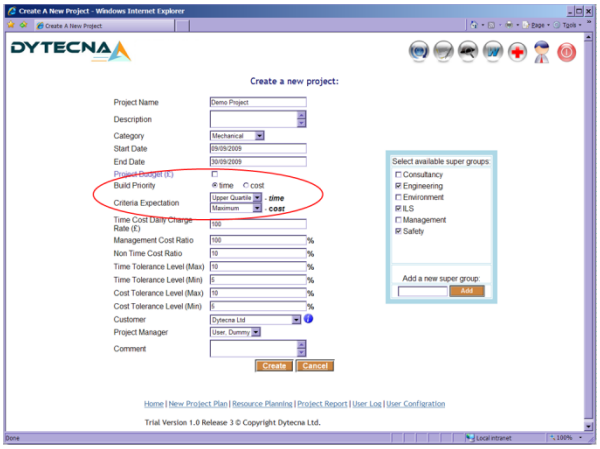

Figure 4. Project Flow Diagram.

The formula below for locating the position of the observation at a given percentile, y, with n data points sorted in ascending order is: $L_y = n \cdot \frac{y}{100}$.

Case 1: If L is a whole number, then the value will be found halfway between positions L and L+1.

Case 2: If L is a decimal, round up to the nearest whole number. (for example, L = 1.2 becomes 1).

Through the formula above and Weighted Mean [15] formula, benchmarked values (Time and Cost) of products can be worked out. Together with the portfolio details such as activities, dependencies and constrains obtained from an identified product from data repository, all these information will be used and stored to create a new product portfolio in WBIMS project. As long as all simple products in the WBIMS project are found as the same or similar to the previous completed products, the benchmarking principle can be employed to choose suitable products. The activities associated with the chosen product will be regarded as the most suitable practices to deliver the product in the new project plan. Actual information collected during this project delivery were stored into the portfolio system to cross check the accuracy of the previous planning to improve the calculation method for future references.

E. System Implementation

The iPAS system was developed using the latest ASP.NET technology and deployed in Microsoft Windows Server 2008 and MS SQL Server 2008R2 under the Windows environment; it takes advantage of many features of the .NET framework 4.0, such as the SQL data source API, integrated AJAX support, Web Services, and a security model that protects data even in Internet applications.

IV. OVERVIEW OF IPAS FUNCTIONS

As a web-based project management system, iPAS is able to intelligently support project managers in project planning, optimising business performance and project cost. The other main facilities provided by the system are: reverse planning, resource allocation, project monitoring and project reporting. Each of the facilities will be introduced next.

A. Project Planning

iPAS enables project managers to plan a project by following pre-defined products (or work packages). It is also the key step of the product-based planning technique in PRINCE2, which has emerged based upon the idea of considering the products that will result from the project rather than how to execute the work [5]. Apart from creating a project plan without applying historical data, users can create a new project plan benchmarking from previous practices and applying desired criteria. In terms of the chosen category of the new project previously matched historical projects will be listed; the users are able to choose the most desirable project(s) from the list to clone. As long as the products together with their associated activities are selected from the desirable project(s) and submitted for assembling; the portfolios (e.g., product name, activity name, dependencies and feedback) will be copied cross to the new project. The effort (time and cost) of each activity will be calculated based on the customised benchmarking criteria and benchmarking algorithms. As a result, a new project Gantt chart (shown in Figure 5) will be generated according to the time effort.

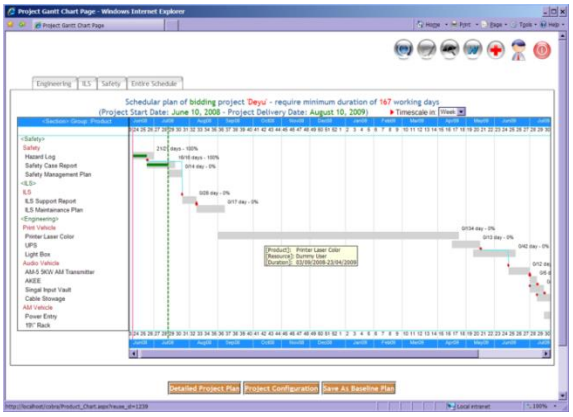

Figure 5. A Project Gantt Plan.

Of course, such automatically derived plan allows manual overrides by privileged users for special considerations such as adding new products, removing unnecessary products or editing the statistics of the effort before the project starts. iPAS also enables users to amend the project ending date or start date after the project plan has been generated, the project plan and Gantt chart will automatically adjust to fit the new duration.

B. Human Resource Management and Profiling

The iPAS provides a basic management of staff resource allocation and activity assignment. It has an embedded

feature to allow the project manager to authenticate staff's work absences and record the period absent, such as sickness, public holidays and off-site training for all project team members. With the help of this feature, the project manager is able to assign available skilled staff into project products (or work packages) and activities (shown in Figure 6). The data of staff allocation together with other project portfolios stored in the database could be used for generating live project resource allocation reports and other analytical reports.

Figure 6. A Product with Activities.

C. Project Monitoring and Alert Mechanism

iPAS provides a mechanism to automatically monitor and analyse product effort values and work completion status during the project progress according to project baseline. This mechanism depends on the regularly entering the actual effort spent by each person or team assigned to the specific activity as soon as that specific activity is completed. The responsible person is also required to enter real effort to complete a task and to comment on environmental factors affecting the delivery result. When the completion box of an activity is ticked, the activity is considered completed. Since activities are associated to products, actual effort can be summarised at product level and even at project level.

Senior members of the project such as project managers are able to check the progress status of all current running projects immediately through a project tolerance Grid chart (shown in Figure 6). This chart provides a project alerting mechanism. There are two levels of alerting mechanism in iPAS: one is at project level and one is at product level. During the project progress, if the position of a project is inside the tolerance level frame but may be over time, over budget or both; the bubble colour will be shown as amber and means the project is still under control but needs to be carefully monitored. The project manager is expected to analyse the problem or look for extra resources. If the position of a project is outside the tolerance level frame, the bubble colour will be shown as red meaning it is beyond the project tolerance level. This situation requires an exception plan to be launched in accordance with PRINCE2 processes. The project bubble colour will be shown as green if the project is on time and on budget. From this Grid view, user (dependent on privileges) is also able to click through the link of the product and find more details in a product view. For each product, there is also a status traffic light indicator designed for the project manager to understand what is due, what is completed and what is overdue (shown in Figure 7).

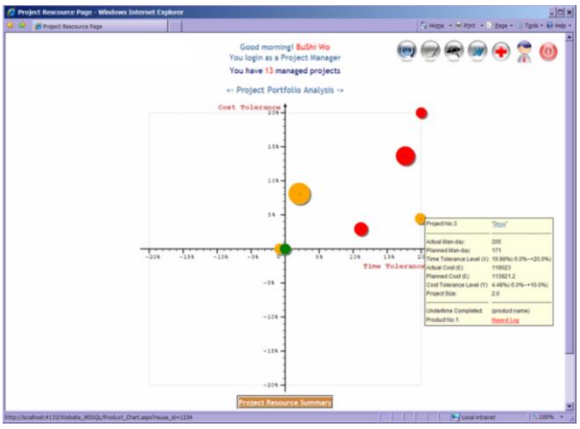

Figure 7. Project Tolerance Grid.

D. Project Report

iPAS is able to generate different kinds of reports with charts according to customer requirements. These reports demonstrate project performance, cost analysis, trend analysis, resource allocation and real-time project status, etc. All these reports can be exported into various formats such as PDF, Microsoft Excel and Word.

E. Summary

Getting everyone consistently using the product based planning method and sharing project information across entire project team and organisation is not easy. iPAS has been developed to bridge the gap between PRINCE2 main principles and its application, providing the user with automated planning, monitoring, reports and human resource allocation. iPAS allows configurable access levels based on roles and rights granted that allow users to access the various management levels and features of the solution based on their individual needs. This approach ensures that each user need only see the functionality and information necessary to perform their responsibilities, thereby making the application easier to use for all stakeholders. iPAS also provides a complete project central database, storing all project data in one location for easy access, saving time and resources. It has built in deliverables' reviews and authorisations are granted online for multi-level granularity cooperation, and progress is updated in real time to reduce the need for costly meetings and expensive time wasting. Accessed across network or intranet, all project staff can share real time project information, best practices and learn from previous experiences with projects; all these enable more accurate future estimating and planning.

In addition, iPAS was designed generically, thus it can be widely used for different industry such as manufacture, education, medicine, construction and rail industries, etc.

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The report formats can also be customised according to the requirements from specific users.

V. EVALUATIONS

Compared with the existing project management applications on the market, iPAS integrates project planning activities with product based planning and automated effort estimation in light of user's criteria. This is a more sophisticated project plan method, which is designed to efficiently support plan creation and adjustment online based on the practices from historical data. With this method, iPAS offers a better guidance to project managers even program managers, because it can help in shaping the plan and a breakdown of global project effort estimates into product and activity efforts, tracking project progress with alert mechanisms, ensuring that the project will meet its goals in terms of PRINCE2 main principles. iPAS also takes advantage of this fact by gathering statistics, which provides assistance during project management. In general, iPAS is specifically designed for managing projects following a well-defined principle, which is typical in engineering projects (e.g., software, electrical, mechanical and construction). iPAS has been tested and validated mainly by a few case studies in manufacturing industry domain and scientific research domain. Major benefits were observed right from a case by six project managers and four domain experts from Dytecna, where a four years project was set under control and transformed into a success by researching the goals which established at the creation of the product based project plan. The iPAS has also been used in two research projects in UK's National Physical Laboratory (NPL), which followed the PRINCE principle in the organisation. It has successfully assisted the program officer to plan the projects with available resources and monitor the progress from start to end. During case studies, The iPAS was applied to help project managers to share the project knowledge for generating project plan and controlling project progresses via product based benchmarking.

Although it is difficult to quantitatively assess exactly how much time and cost were saved for project planning and management in the case study, users who have used the iPAS system summarise the following major advantages against the traditional project management method:

- It allows the company to continuously improve both bidding, planning and project management as well as reduce risk
- It is a novel approach to store and share information among different projects
- It is an innovative method to integrate PRINCE2 and benchmarking principles
- It reduces project starting up and initiation time, reduces management costs by limiting the number of project meetings conducted
- It wins more work for a customer by providing accurate rather than estimated information on costs and duration at tender stage. Thus, a company has more confidence in the accuracy at ITT (Invitation to Tender) responses, customers have more confidence in bids made and associated cost profiles
- Company is able to justify through life costs and plan resources to serve contracts, thus to improve company success and profitability
- Company has continuous improvement in data accuracy providing early identification of the program that is moving toward an adverse situation
- It's adaptable to any other sectors such as construction, rail industries, health services or government, etc.

TABLE III. CULTURE CHANGES BEFORE AND AFTER USING IPAS

Stages	Pre iPAS	Post iPAS
Bidding	Ad hoc and configuration No historical data, estimation based on expert judgment No follow up, no lessons learned	Historical data are available to improve estimation Resonation and improvements of the process
Planning	Activity based planning Last minute identification of the activities	Product based planning, activities can be referred from best practice
Monitoring	Difficult to follow the evolution of a activity or to assess the quality of the completed work	Easily to monitor the progress of the project by watching the delivery quality of products and practices underneath
Control	Hard to know the failure reasons from project team level and response immediately	Failure point can be easily spot out and then take necessary action quickly

Table III shows the culture changes observed using iPAS software in NPL and Dytecna. Before introducing iPAS tool, the project plans were generated based on experts experience probably, in most cases, the lessons learned from previous projects are easily forgotten, and project activities were planned without a clear idea because there is no precise intention on what is going to be delivered. By recording what was done and how much effort was spent, project team members could now easily monitor and control the project progress, accurately assess what they were doing from an objective perspective, as well as learn the lessons from the past.

VI. CONCLUSION AND FURTHER WORK

iPAS is a web-based project planning and management tool adapted to the product based planning techniques of PRINCE2, which can be applied to standardised industries such as Construction, Logistic Support, Electronic and Mechanical Systems Engineering. It guides the project manager by recycling historical data and best practices to estimate project resources and to cascade this into manageable products. iPAS provides focus on project objectives, by structuring a plan based on products, by facilitating accurate monitoring of these products throughout the project. These features assist the project team to

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maintain programmed activities and to meet contract commitments, whilst reducing the management overhead. It can be deduced from the above sections that iPAS already is capable of providing considerable added value in many areas of project management. However, it has become clear to the development team that there are several ways in which iPAS could be further enhanced.

A possible extension could be to link iPAS database with an organisation's host database. As iPAS collects more and more business practice data from a variety of organisations, there is a need to establish an appropriate knowledge base centre. An external benchmarking comparison service also could be provided in order to coordinate with the unique company database system and bring in external knowledge, which will enable the customer to manage the business more efficiently. The future work can also be focused on enhancing human resource management, enhancing the user interface, perfecting the navigation and strengthening the statistical robustness of the system, etc.

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