An integrated system for ship construction projects control using risk analysis

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Abstract

The Brazilian shipbuilding industry is presently showing significant recovery prospects. However, there are some problems affecting this process. The high level of builder's risk perceived by the owners and, mainly, by banks, insurance companies and other stakeholders, is likely the most critical.

The main instrument to keep the risk in acceptable levels is a strict control of the construction progress. However, some shipowners have been employing control systems that are excessively complex, detailed and expensive, but, at same time, not sufficiently effective.

This paper presents the main characteristics of a computer system developed to provide a broad control over the construction progress and financial balance as well as a continuous risk assessment.

Keywords

Shipbuilding, project management, risk analysis, 4D-CAD visualization.

1 Introduction

The Brazilian shipbuilding industry is presently showing a process of recovering and expanding. However, there are some hindrances affecting this process. The most critical problem is probably the high level of builder's risk, as perceived by owners, insurance companies, banks and other stakeholders.

The Brazilian shipbuilding had a period of rapid expansion in the decades of 1970 and 1980, reaching the second position in the shipbuilders' world ranking, in 1979. The Brazilian shipbuilding growing was supported by governmental protection and incentive polices. However, due to a number of reasons (Pires (1999)), in the mid eighties a deep crisis has started. Most of the main shipyards got closed for some years. Only in the beginning of the last decade, the shipbuilding activity has started again.

The Brazilian shipyards have always had difficulty in accomplishing the contracted terms. Even for the period of more intense and continuous production, the records show systematic delivery delays and cost overruns. After that, during the crisis period, the main Brazilian shipyards, as well as the other components of shipbuilding supply chain, experienced even worse performance problems,

*Submitted to MS&OT on October 31 2012. Revised version submitted on July 03 2013. Accepted on July 20 2013. Editor: **Waldir T Pinto.***
Article posted online on November 30, 2013: URL: www.sobena.org.br/msot/volume.htm

resulting in an extremely unfavourable risk record. In the present recovery process, there is a high degree of uncertainty affecting both the existing shipyards, under recuperation or modernization, and the new greenfield plants.

As a consequence, in present day, new contracts have been impeded by the lack of confidence of some private owners, and by the shipyard difficulty in structuring warranties and providing performance bonds or refund guarantees.

An important instrument to keep builder's risk within acceptable limits is a strict control of the progress of the construction project. However efficient control systems, services or tools are not normally available. Some contracts are conducted under a weak supervision or no supervision at all. On the other hand, some shipowners have been employing control systems that are excessively complex, detailed and expensive, but, at same time, not sufficiently effective.

This work presents the main characteristics of a computer system developed to provide a broad control over the construction progress and financial balance as well as a continuous risk assessment. The system is based on a systematic and comprehensive approach to shipbuilding project management. The main goals of this approach are:

- To be capable not only of identifying problems already occurred, but also of indicating problems likely to occur in the future.
- To have the flexibility to be easily configured to meet different models of contract, relationships between the shipyard and the other stakeholders and levels of builder's risk.
- To have the required flexibility to provide customized reports fitting the specific needs and the profile of each client.

This paper is organized in 6 sections. Section 1 presents the introduction. Section 2 presents the proposed methodology for supervision and control of shipbuilding projects. Section 3 presents the methodology used for risk continuous analysis in shipbuilding projects. Section 4 discusses the issues related to financial control. Section 5 considers the proposed system to visualization of the construction progress. Section 6 outlines the main features of the computer system proposed to implementing that methodology. Finally, the final section presents the concluding remarks.

2 Supervision and control methodology

A system designed to project control is required to be flexible enough to adapt to different detailing levels adopted in the supervision process. The best configuration of the system for a particular shipbuilding project will depend on the characteristics of the project or contract, as well as the kind of agent who is interested in controlling the project. This agent might be the shipowner or other stakeholder, as a bank or an insurance company. Project features that are relevant for configuring the control system would be, for instance, the product complexity, the quality of the shipyard's information system, the shipowner (or stakeholder) risk tolerance and perception of builder's risk, and, mainly, the type of contract (fixed price, cost plus or some combination).

The control of the physical progress of a ship construction may be performed through the verification of a few milestones, or may be based on the control of a large number of activities, with measurement of costs and man-hour consumption. The control of financial flows may be required or not.

In Brazil, most shipbuilding projects are financed by the state owned Development Bank. The funds made available to finance ships are provided by a governmental fund, the Merchant Marine Fund (FMM). The FMM grants very favourable financing conditions to ship-owners for building in domestic shipyards. Virtually all merchant ships built in Brazil in the last 50 years were financed by the FMM, Pires et al (2005). The FMM and the Bank adopt quite unique contract standards and managerial practices.

The financing projects are approved on the basis of a statement of construction costs. The shipyard and the buyer freely negotiate the price and delivery time. However, in order to obtain the FMM financing, they are required to submit a detailed budget, in a standard form. The amount to be financed corresponds to the budget approved by the FMM authority.

During the building time, the Bank performs a rigorous control on costs and financial flows. Nevertheless, there is not control of physical progress compatible with the detailing level of financial control and there is no risk analysis at all. As a consequence, the control system is inefficient in identifying delivering delay and cost overrun provoked by problems related to design, production or supply chain. Moreover, the system has no capability for foreseeing future problems.

The risk allocation between builder and buyer, as well as third parties participation, as financiers, insurers or guarantors, may largely differ from contract to contract. Consequently, the need for control is also variable.

There are buyers who, having available resources and technical staff, and bearing large risk shares, adopt complex systems for supervision and control of the building process. This kind of system includes measuring the accomplishment of a large number of activities. However, these systems are soon too expensive and inefficient. They normally do not include any risk analysis, so they do not have the capability for anticipating future problems. The financial control tools and the integration between financial and physical supervision and control are normally insufficient.

On the other hand, insurers and guarantors usually rely on information and reports from builders or buyers, and do not conduct any specific supervision and control activity.

Normally, the contract schedule and budget are based on the work breakdown structure (WBS) and financial schedule standards that are required by the FMM and the Bank.

The system proposed in this paper was developed to have flexibility to work with any level of project activity network detailing, both to modelling the schedule and allocating labour, material and services costs. Although the user can introduce the activity network and budget based on any WBS model, the system take as default the FMM standards. The project configuration is achieved starting from the standard model, through a quite user friendly interface. Fig 1 shows a typical WBS constructed on the basis of the standard model.

Fig 2 illustrates the third level of WBS (WBS3), related to WBS1 = CONSTRUCTION, and WBS2 = HULL STRUCTURE, for two different examples. In the first case (Fig. 2.a), the activities that will be the object of supervision and control are steel processing, assembling, pre-erection and erection, for each element of the hull, split in rings and blocks. The second example (Fig. 2.b) corresponds to a simplified control system. In this case the activities refer to the hull as a whole, without any subdivision.

The allocation of resources and costs to the WBS activities is done by direct allocation or by aggregation and apportionment.

The project activity network is developed starting from the WBS, then incorporating information on activities duration, resources, links, restrictions and milestones. The network may be based on importing the project network elaborated by the shipyard for planning the construction. In this case, the network for control purposes will probably need to be simplified by merging activities or WBS elements. On the other hand, if a simpler control is required, it could be more efficient to create the network directly, from scratch. The more complex the control network, the more it is similar to the shipyard´s planning network. Then it becomes more efficient to import and customize.

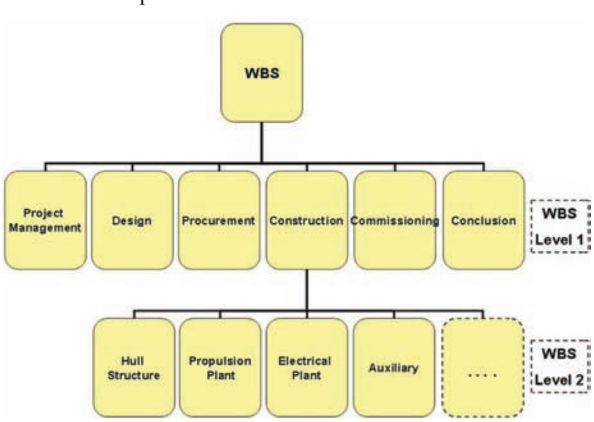

Fig. 1 Typical Work breakdown structure – WBS.

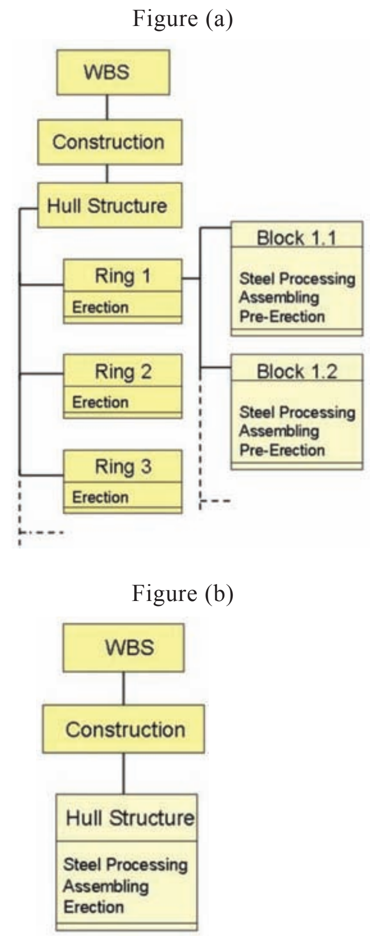

Fig. 2 Examples of WBS.

The basic structure of the control network is completed by the Organization Breakdown Structure – OBS, which contains the supervision team composition and organization, including shop floor inspectors, office staff engaged in procurement and financial control, and analysts. The OBS defines the system access authorization rules, and who is responsible for entering any piece of information.

The control of project progress is performed on the basis of a conventional EVM – Earned Value Management approach, PMI (2008). EVM integrates the management of project scope, cost and time. In the system described in this paper, the EVM project control is performed by using available commercial project management software. The system was designed to interface with a broadly used project management system. The basic tools of that commercial software are employed to progress monitoring, tracking reports and control of scenarios. The key performance indicators (KPI) for time and cost performance are the standard SPI and CPI. Accordingly with the conventional terminology, the Schedule Performance Index – SPI is defined as the ratio of earned value to planned value, at the date of analysis. The Cost Performance Index is defined as the ratio of earned value to actual cost. SPI reflects the efficiency of the time utilized on the project, and CPI shows the efficiency of the utilization of the resources on the project. These indexes are employed to analysis of performance, detection of problems and forecasting time and cost to completion.

Fig. 3 shows an example of a set of EVM monitoring curves generated by the system, based on the basic results from the commercial software.

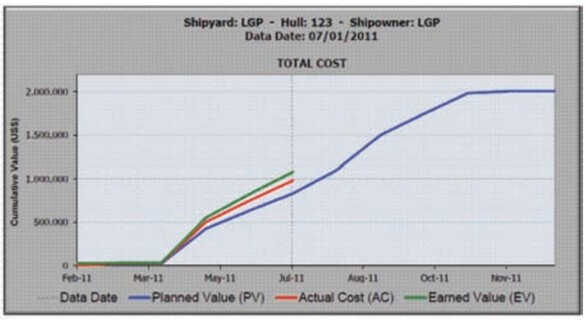

Fig. 3 Earned value management indicators.

The set of standard reports can include, besides the global EVM curves, curves for specific WBS elements, as for example, HULL CONSTRUCTION. The system can be also configured to include partial cost curves, as total labour cost or steel working labour cost.

Conventional EVM provides very valuable information. However, it presents two important limitations: does not provide information on project financial health; and indicates only problems that have already impacted the project progress, i.e., problems whose effects already can be observed. To incorporate the capability to anticipate future problems would be extremely important.

The first limitation should be addressed by introducing further indicators and financial control procedures, associated to EVM. The second requires the monitoring of risk factors, and continuous risk assessment.

3 Risk analysis

Risk analysis is an increasingly used tool in management of projects and contracts. Nevertheless, there is not a significant literature on shipbuilding risk management. There have been few studies about risk assessment in the shipbuilding industry. A remarkable (possibly the only one) example is the work by Lee et al (2007), dealing with risk identification for the Korean industry.

The continuous risk analysis methodology used in the system can be summarized as follows.

Firstly, a risk identification process is performed and a Risk Breakdown Structure (RBS) is prepared. A general risk identification process was carried out by Pires et al (2009), which aimed at the identification of risk structure for the Brazilian shipbuilding industry as a whole. The risk structure identified at this level can be useful as an input to the risk analysis in specific projects, or in analyzing specific shipyards or group of shipyards.

Secondly, a system is described, which aims to monitor the main risk factors along the building time and to update the overall risk analysis when necessary. The analysis is based on Monte Carlo simulation of the project network.

The project activities network is analyzed considering the uncertainties in the duration and cost of each element, as well as the critical external and internal risk events between contracting and delivery. Risk events are identified on the basis of a general framework of critical risks, which shows the level of probability of occurrence of each risk event and the respective level of impact, both in costs and schedule. The impacts are estimated regarding the main phases of a ship construction contract.

The process is continuous, as the monitoring network is updated, new indicators are generated and further analysis should be made. The analysis allows the estimation of probability distributions of total and remaining cost and delivery time, in any time during the building period.

At each monitoring and control cycle, the system generates a set of statistics that allow for the re-estimation of durations and costs probability distributions. Further, the analyst must update the analysis of external risk factors. At each cycle, after concluding these tasks, all the previous steps must be run again.

The outputs of the continuous risk analysis, like expected time (Fig 4) and cost (Fig.5) to completion, are included in the set of standard pieces of report, available at each control cycle. The risk analysis model can be used to support decision-making about changes in the project or adoption of appropriate mitigation actions.

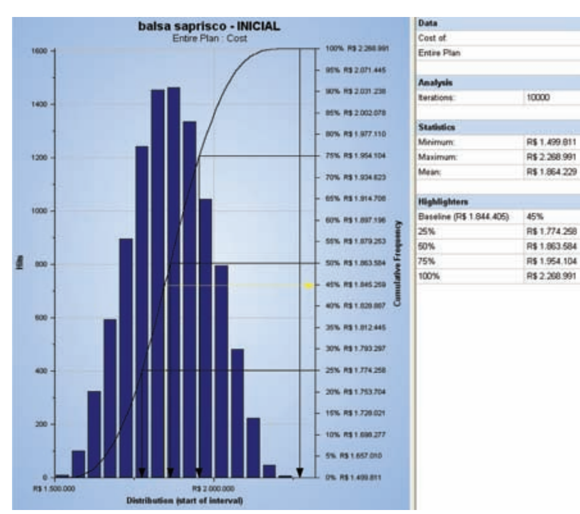

Fig.4 Probability distribution function – final cost.

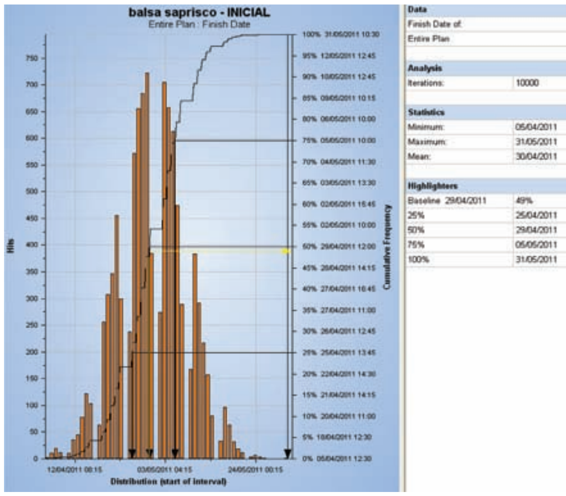

Fig. 5 Probability distribution function – finish date.

4 Financial supervision and control

The proposed system includes a module dedicated to Financial Supervision and Control that involves the following main functions:

- Cost accounting;
- Financial flows monitoring, control and reports;
- Key financial performance indicators evaluation and assessment;
- Acquisitions, invoices and payment control;
- Foreign exchange operations.

The EVM progress curves indicate the earned value, actual cost and planned value related to the work already done. However, comparing these figures with disbursements by the owner or the Bank would give a distorted vision of the project financial status. The problem is that some resources already incorporated to earned value may be not yet paid, and, on the other hand, resources not yet incorporated may be already paid.

The first output of the module dedicated to Financial Supervision and Control is the progress curve of Investment, which corresponds to the total amount of disbursements already done. This indicator is equal to the earned value plus the cost of the items already paid and not yet incorporated, minus the cost of the items already incorporated and not yet paid. Fig. 6 shows an example of the chart that gives a more realistic picture of project financial balance. The figure includes, along with the basic EVM curves, that Investment curve, as well as the cash flow curve. The project cash flow corresponds to the total amount transferred to the shipyard by the owner and the Bank. These indicators allow for the analysis of relevant issues, as the actual cost overrun and the anticipated overrun at completion, under different scenarios.

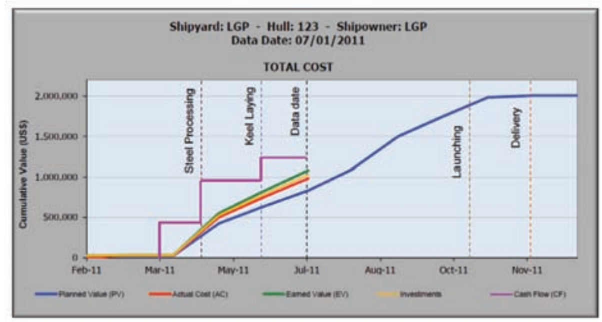

Fig. 6 Extended EVM chart.

Aiming to improve the monitoring and control capability of the tools usually available in general project management systems, the system proposed in this paper reports several indexes that are useful for the analysis of the project economic and financial status and performance. Standard financial reports include Cash Flow Statement, Debt Composition, Leverage Indicators and Liquidity Indicators, like Current Ratio and Quick Ratio[1].

A further function of the system of financial supervision and control for shipbuilding projects (at least) in Brazil is to monitor and control the amounts paid and to be paid by builder and buyer.

In a typical Brazilian shipbuilding contract, the price risk of some inputs is fully borne by the buyer and some others, fully borne by the builder. There are also cost items with automatic correction clauses, aiming to compensate inflation or exchange rate variation. In the case of such items, the buyer is supposed to pay the budgeted price, plus the difference due to correction by the relevant index. In this (quite usual) type of contract, to control the already done and outstanding payments by the buyer is a critical task. An efficient project control system must include tools for updating the correction indexes, as well as for forecasting future payments, both to short term and to completion.

5 Visualization

On the owner's (or other stakeholders') side, several kinds of agents may exist interested in monitoring and controlling a shipbuilding project: project manager, engineers in charge of

[1] *Current* Ratio measures the ability to pay short-term obligations (CR = current assets ÷ current liabilities), and *Quick Ratio* is an indicator of short-term liquidity (QR = (current assets – inventories) ÷ current liabilities).

specific sectors (structure, outfitting, design, procurement, etc.), CEO, etc. Each agent requires a specific set of information. Therefore, the system is required to be capable of customizing the navigation in the reports environment. Particularly in the case of CEO or other high level executives, who are interested in a broad view of the project progress, the availability of powerful visualization tools is important.

The proposed system has 2 visualization modes:

- Real time images;
- 4D-CAD visualization.

Real time images are captured by cameras positioned at strategic points in the shipyard, as pre-erection areas or dry docks. The user can select the relevant image and access it in real time.

The system also has 4D-CAD capabilities, Jongeling (2007).

At the system setup, for a specific project, the user selects a model for building progress visualization. The selection is performed by associating given activities with visualization CAD units. The CAD models are selected from a model library that includes simplified 3D representation for each ship type. The status of activities is indicated through a colour and texture code. Three status levels are considered:

- Completed
- Scheduled (planned completion date yet to come)
- Delayed

There are available visualization models to hull structure (3D), machinery and auxiliary, key equipments, painting and outfitting. Fig. 7 shows some standard CAD models. Fig. 8 illustrates the hull structure of a Suezmax tanker at 2 different construction stages. Fig. 9 illustrates the kind of real time image that may be available.

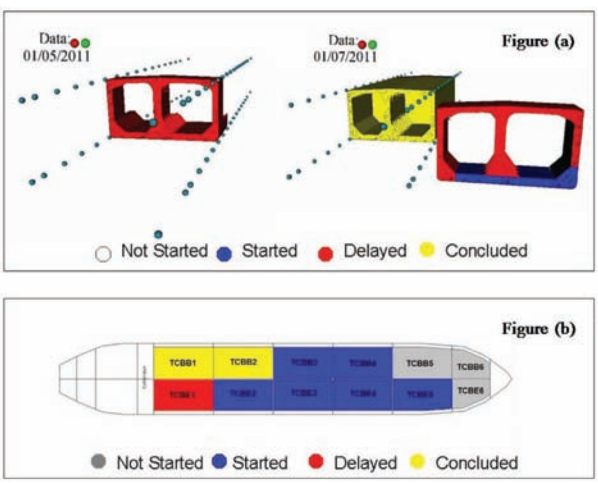

Fig. 7 Standard visualization elements: (a) hull erection and (b) painting of cargo tanks.

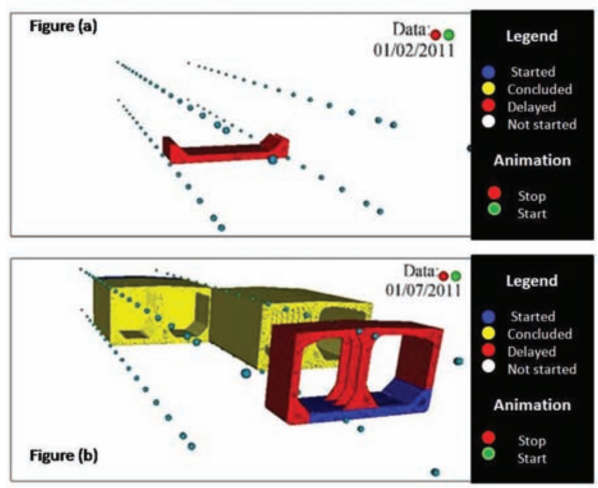

Fig. 8 Hull structure visualization example: status of hull erection in (a) February 2011 and (b) July 2011.

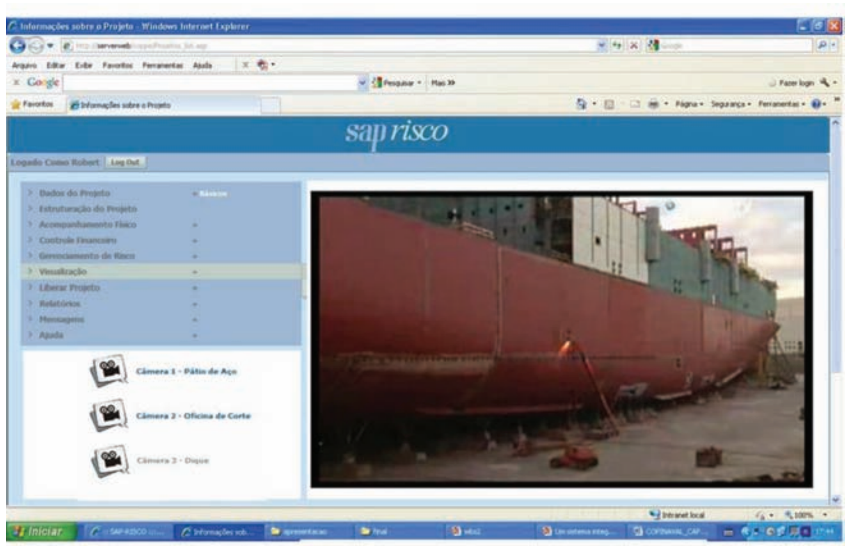

Fig. 9 Real time shipyard visualization.

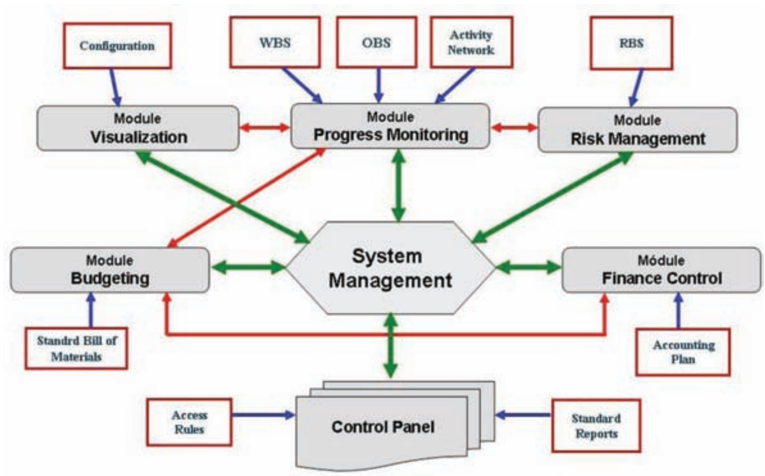

Fig. 10 Computer system architecture.

6 Integrated computer system

A computer system was developed aiming at implementing the methodology and tools previously discussed. The system was designed to have the required high degree of integration between the modules, as well as the flexibility to adapt to different kinds of projects and user profiles. Fig. 10 presents the general architecture of the system.

The system is based on web distributed architecture. The data may be input from multiple sources, like a portable device at shop floor or a desktop computer at client's office. Also, the reports may be accessed by users at different sites.

As indicated in Fig. 10, the system consists of 6 operational modules that perform the operations of input basic project data, monitoring the progress, controlling the documentation, processing the graphical computing and executing financial indicators calculation, earned value analysis and risk analysis. The main system's functions and methodology was previous broadly discussed.

The System Manager module is responsible for the setup of new projects, definition of general system configuration and user profiles, control of access, posting of customized report, and managing other project-related particulars. The module controls the information flow and the sequence of monitoring and control tasks.

7 Concluding remarks

The development of methodology and computer tools for shipbuilding projects control and monitoring is a relevant research object. This is particularly important in situations where the builder's risk is an obstacle for the industry development or imply excessive cost burden. In the case of Brazilian shipbuilding, this problem can be considered the main concern in the present recovery process.

This paper had the objective of discussing some relevant issues related with the general problem of project supervision, monitoring and control in the commercial shipbuilding environment.

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