The Application of SDPM, Critical Chain and Portfolio Project Management Principles to the Construction of the 670 km Urucu/Manaus (Petrobras) Pipeline

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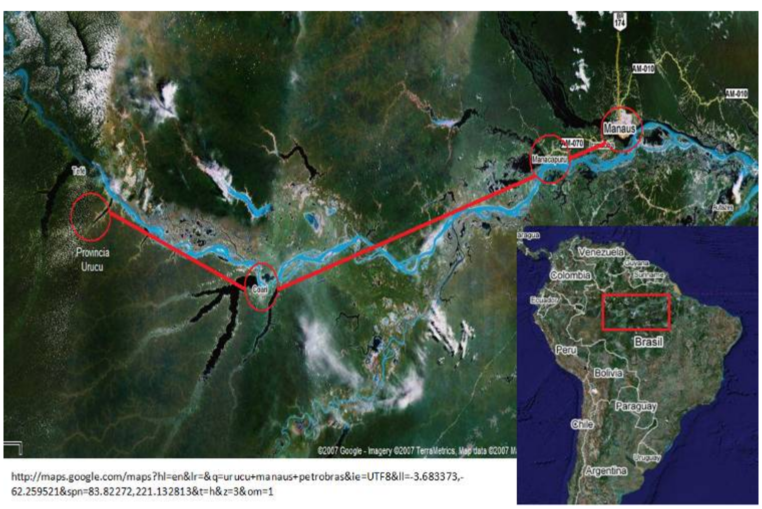
Abstract

Dealing with thousands of team members, many contractors and a huge gas pipeline construction is not a simple task. If we add a couple of dozen rivers to be crossed and heavy tropical forests in the middle of the Amazon, we then have an outrageous environment that demands outstanding project management. The Urucu/Manaus Gas Pipeline (Amazon/Brazil, Petrobras) is under construction and has suffered a severe set of problems from its beginning. Efforts to increase productivity to deal with tight schedules are being taken by several teams involved with the construction and at Planning and Controlling Headquarters. This paper describes how we are developing new scheduling plans with the assistance of "Critical Chain", "Success Driven Project Management" and "Portfolio Project Management" techniques. The first challenge was deploying an effective Project Management Information System and establishing effective communication channels among all the functional areas that participate in such project.

Because of hierarchical relations among several areas of Petrobras (believed to be the largest company in all of Latin America), we realized that each functional area has its own agendas and projects and the common approach for program or project management doesn't do the trick when organizing a final project plan for the enterprise. We added aspects of Portfolio Project Management as a means of prioritizing efforts and resources, organising and prioritizing individual projects and achieving strategic goals for this huge construction challenge.

Picture of the Urucu/Manaus Gas Pipeline taken in December, 2006. [MostraTic, page 1]

Introduction



http://maps.google.com/maps?hl=en&lr=&q=urucu+manaus+petrobras&ie=UTF8&ll=-3.683373,-62.259521&spn=83.82272,221.132813&t=h&z=3&om=1

This project, in the state of Amazonas (Amazon, Brazil) is undertaken by IENOR (a Petrobras unit for the development of engineering projects in the North of Brazil). IENOR's mission is to implement projects for gas, energy and pipeline transportation for expanding the national energy matrix in Brazil. "The Urucu-Manaus pipeline will be 670 kilometers in length with conclusion scheduled for March 2008. In the first stage of its operation, the pipeline will transport 4.7 million cubic meters of natural gas daily. The gas will be used largely to supply the thermoelectric power plants generating electricity to Manaus and the municipalities adjacent to the pipeline. The natural gas will substitute diesel and fuel oil currently used to generate all the electricity produced in the state of Amazonas… In addition to the economic advantages, the substitution of existing fuels by natural gas will represent an enormous environmental gain for the

Country. Production of electric energy from natural gas significantly reduces emissions of polluting gases, especially carbon dioxide (CO_2), thus contributing to a reduction in the greenhouse effect in line with the Kyoto Protocol, to which Brazil is a signatory." [Petrobras/SECINFO, page 1]. When dealing with such challenge and after initial delays provoked by the difficulties in mobilizing the manpower and equipment necessary, the Planning and Controlling area of IENOR decided to seek new ways of organizing its project, with the mission of finding alternatives to increase productivity and restoring the possibility of finishing the project by the planned date (March 2008). By December of 2006, when the studies for new approaches were being taken, the productivity was far below that expected, thus pointing to a new completion date past 2009.

Success Driven Project Management Methodology

The proven Russian methods called Success Driven Project Management (SDPM) (Liberzon and Archibald 2003), (Liberzon 1996, 2000, 2001) have been applied to this pipeline project, providing the necessary alerts to provoke a set of changes in strategic areas of the project. SDPM is based on a set of indicators measuring project performance and forecasting its final success. The information system that has been implemented supplies the project management team with the following information:

During the planning stage:

1. Project target dates, costs and material requirements that could be achieved within the user defined probability of success,
2. Probability of achieving implied project (phase) goals (scope, time, cost, and material requirements) – "success probability", and
3. Time, cost and material contingency reserves that should be assigned to support achieving project goals with the necessary or desired probability.

During execution and control:

1. Current probability of achieving various project goals,
2. Success probability trends that could be used for determining necessary corrective actions (it is worth mentioning that these trends depend not only on project performance but also on changes in project risk characteristics), and
3. Current contingency reserves.

During project execution the project manager should control the current success probability and its trends. This information is the most useful for estimating project performance and deciding if and what corrective action is necessary.

The SDPM methodology is based on the *resource critical path* approach. This approach has common features with the Critical Chain/CC and the theory of constraints (Goldratt 1997) and includes:

- Calculating the critical path *taking into consideration all schedule constraints including resource and financing constraints,*
- Calculating *resource constrained activity floats* (analogue of the CC feeding buffers),
- Calculating *resource constrained assignment floats* and determining *critical resources*,
- Project risk simulation and calculation of the *success probabilities*,
- Calculation and management of the *contingency reserves* (analogue of CC project buffer).

By controlling current values and trends of the project success probabilities the project managers have powerful tools that make project performance analysis very informative and even easier than the traditional Earned Value methods.

Need for Integrated Information: Effective project planning and control requires that the information regarding project scope, schedules, resources, finances *and related risks* be integrated at detailed and summary levels. This requirement has been recognized for many years but it has not often been achieved in practice.

Integration Methods Used in SDPM: Integrated scope, schedule, financial and risk management for projects is achieved in the SDPM approach using these methods:

1. Scope is defined systematically using appropriate breakdown structures that inter-relate all project information. The work scope or volume is estimated for each task, work package, or activity, together with the types of resources required and the planned rate of usage or resource productivity for each activity.
2. Sequential, logical dependencies of work and deliverables are defined using appropriate network planning methods.
3. Resources are:

a) defined as consumable and renewable; they can be utilized and produced on project activities,
b) estimated as independent units, units in teams or crews, or interchangeable units within assignment pools;
c) assigned to project activities; and
d) considered as constraints when their limits of availability are reached in calculating the project critical path, in both forward and backward pass calculations.

4. Activity durations are calculated, when appropriate, by combining work scope or volume with resource usage or productivity rates.
5. Risks are calculated by simulating risk events and using a range of three estimates where appropriate for 1) work scope and volume, 2) resource usage and productivity rates, 3) activity duration when estimated directly, and 4) calendar variation for weather and other factors, to produce predicted probabilities of meeting the desired target schedule dates and budgets.
6. Project schedules are produced in the usual manner by processing the network plans, but most importantly the true critical path is calculated to reflect logical and all schedule constraints, including resources, in both the forward and backward pass calculations of the network plans. This has become known as the **resource critical path/RCP** to emphasize that resource constraints have been used in determining which activities are truly critical to project completion, and in the calculation of available float or allowable delay.
7. Actual expenditures of time, money, and resources are compared with plans, schedules and budgets to enable effective project monitoring and control.
8. The current probabilities of success in all areas (schedules, resources, financial) are calculated, and their trends are determined and presented graphically through analysis of frequently revised and retained project plans. Initially the desired targets for project dates, costs, and material or other resource requirements are calculated based on the desirable probabilities set by the project manager and planner. If the target data are set then the system calculates and the project planner evaluates the probability of their successful achievement.

Results Achieved Using Portfolio Project Management and SDPM

A new Project Management Information System was put in production from October 2006 to February of 2007, this time considering resource restrictions under the views of Critical Chain and Success Driven Project Management. The necessary changes in management also included a new approach regarding priorities given for several subprojects taken by different functional areas of Petrobras/IENOR. The concept of a large enterprise with special strategic goals transformed the group of subprojects into a larger Project Portfolio.

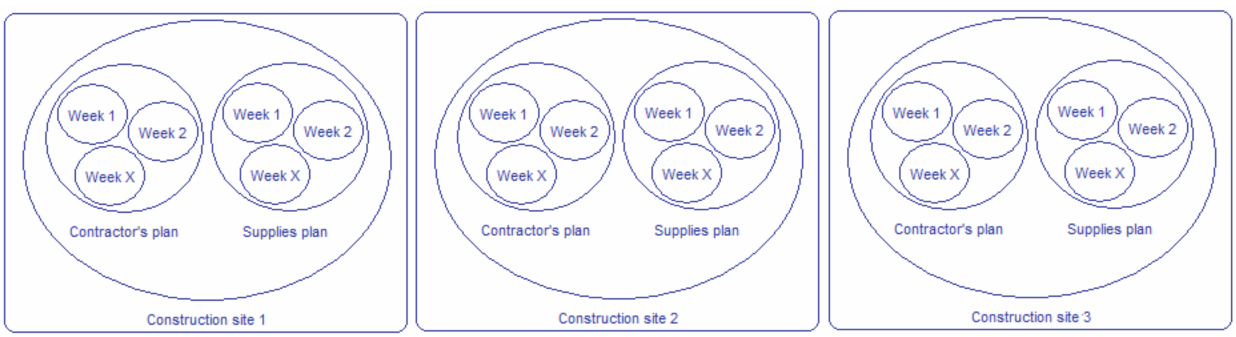
While project management specialists would say that all projects undertaken for this enterprise should in fact be treated as a large project with many subprojects or even as a program, we chose to deal with conflicts of interest among projects by classifying them under a Portfolio. The hierarchical structure given to the many functional areas of Petrobras/IENOR created a set of smaller projects taken by each functional area that sometimes would compete for important resources of the strategic project that should tie these functional areas together. By seeing IENOR as a "company" and the construction of the gas pipeline as its strategic goal, any projects taken by any functional area should then be identified, prioritized and controlled under a portfolio perspective (see Archibald, pp 12-15, 174-179.) The major cultural changes imposed on the dozens of managers responsible for the pipeline were structured and managed under the view of constrained resources within an overall Urucu-Manaus Pipeline Portfolio.

Setting new goals: Initial estimates created for the project took in consideration the productivity found in some pipeline constructions in many parts of Brazil but were not enough to predict the reduced ability of the teams to work under continuous tropical rain. Some drained areas of the construction in the first semester of any given year would simply be found to be under 12 meters of water in the following semester. The lack of a model that would evaluate the project in three estimates (pessimistic, optimistic and most probable) had produced a schedule that soon proved to be completely unrealistic. One of the biggest challenges is the fact that Petrobras is responsible for the construction regarding the compromises with investors and financial institutions but the daily construction is set by contracts with different service providers. Therefore, even when changes are necessary to the contractor's work routine, Petrobras cannot impose a new set of rules to these providers. The SDPM team is then a consulting group that provokes the contractors to change their approaches by measuring progress and indicating alternatives, with no rights over the final decision if such alternatives would ever be applied.

As a result, we have a very delicate balance of power between functional areas and different contractors. With the implemented Project Management Information System (PMIS), the SDPM team gained acceptance from other stakeholders by intensively collecting all possible information about the project and creating supporting reports to different areas. After a couple of months from the PMIS implementation, the reports were sufficient to help a major negotiation between Petrobras and the contractors to accommodate working changes to the enterprise. At this point, the construction had reached 50% of the original planned time with a Schedule Performance Index under 15%.

If we consider the normal path for the introduction of a new methodology, we should consider that such methodology would first be presented during the planning stages and then used all through the life-cycle of the project. In this project, the SDPM was brought to the project already in the late executing stages. If we consider the PDCA cycle (planning, doing, controlling and acting), the adoption of SDPM is in fact a result of a new "acting" stage after many cycles of planning, doing and controlling were not sufficient for the job. With disrupted schedules for different groups working in the construction, the SDPM team started to promote the necessary steps to fulfil the needs for integrated information discussed previously. We reduced the time from planning and controlling each step in the construction by evaluating schedules that would not be longer than 15 days each.

While we reduced the "time span" for the project, we expanded many times the level of planning details requested from the contractor. In fact, instead of getting a huge schedule with milestones set from day one to the last day of the project, what we started to have was a very detailed schedule for the following two weeks. All the necessary resources, all the estimated production rates, and all available information about each part of the construction were then controlled using the new PMIS. For each of the following weeks, several new short plans were delivered to the SDPM team. We created a large Portfolio set with many small projects and slowly started to gather such projects into small programs. This way, we could finally create an integrated view showing not only financial and physical aspects of the construction, but also the relationship of them to projects conducted by logistics and supplies.



(Figure shows the set of weekly small projects put together to create a bottom-up Work Breakdown Structure)

The resulting integration of these many small projects could be seen as the construction of a bottom-up Work Breakdown Structure for the main project. When registering "planned versus executed" for each of the small projects, we could then adopt the "success probability index" measuring trends and created resource-critical-schedules that were not possible before.

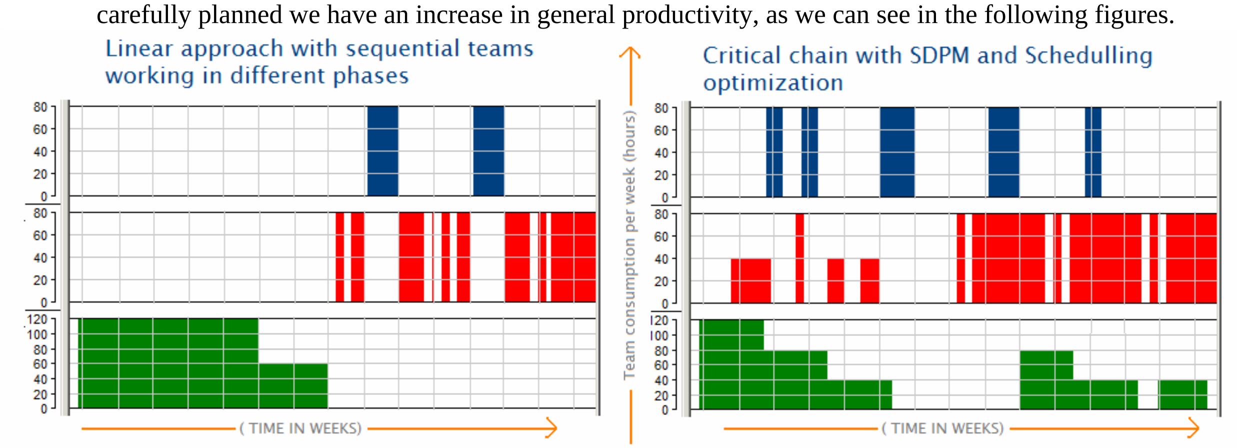
A bit of history:

- The first stages of the project are dated from July of 2004, when initial topographic studies were made, along with environmental studies.
- During the year of 2005 several biddings were made to establish the many contractors for the construction. Due to difficulties in the region for measuring the work to be done, there were no actual responses from probable contractors that found the whole enterprise to be too risky.
- In early 2006, with the help of the military engineering brigade, Petrobras opened the first roads through the jungle and established camping sites for the storing of many tons of pipe. New negotiation with contractors finally resulted in a late start (July of 2006) with the mobilization of a huge number of people and machinery to be done during the dry season. It was known that such mobilization wouldn't be completed immediately and the best period of the year for the pipeline construction had been missed. Heavy rains started in November and were not over until June of 2007.

- In August of 2006, Petrobras realized that they had to take extreme measures for improving productivity. In October of 2006 a team was formed to start a study to propose changes in the project that could compensate the late start and the necessary changes for the year of 2007.
- In December of 2006, the team concluded the implementation of a Project Management Information System based in the Russian solution Spider Project Professional.
- From January to April, the team collected information about the ongoing operations; this was used to simulate alternatives and give an opportunity for Petrobras and the contractors to calculate new needs of materials, people and changes in the logistics.
- By the time the changes were starting to be implemented on the project (May, 2007), we had reached 50% of the original planned time for the construction with only one third of the planned work accomplished.
- In June 2007 the SDPM team was formed and created a war room to prepare the necessary changes for the project.
- In July a new Work Breakdown Structure was completed that integrates several efforts under the Portfolio perspective. The expected results include faster data collection in the field for quicker logistic changes with personnel and machinery.

Slowing down to speed up the project:

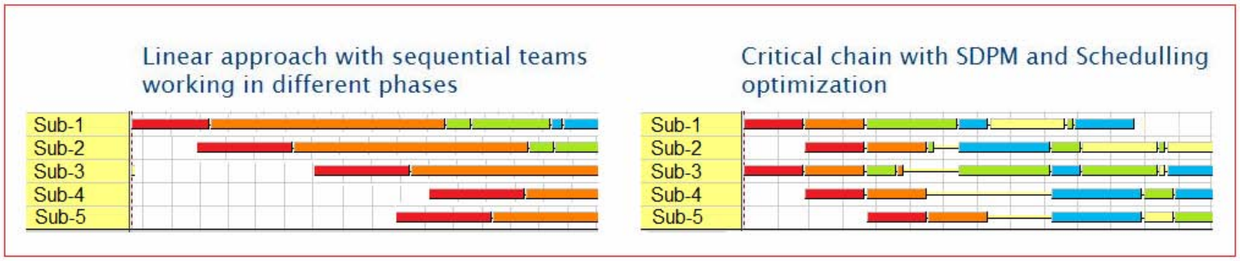
- What is expected with the adoption of Success Driven Project Management (with many concepts known by Critical Chain adopters) is the ability to identify what phases of the project should be delayed to make critical resources available to other critical phases, thus expanding the productivity in areas of bigger working dependencies with other teams.
- SDPM includes a risk analysis of different segments of the project, and using optimization of the scheduling with resource restrictions with Spider Project it was possible to improve general productivity.
- In short, by transferring resources dedicated to the opening of new construction paths to the transportation of pipelines will delay one phase of the project for improving the second phase. When such logistics are carefully planned we have an increase in general productivity, as we can see in the following figures.



The previous figure demonstrates that by "slowing down" some phases to distribute machinery and personal to more critical areas makes it possible to improve the general productivity. Simulated schedules demonstrated that in some cases we will expect gains of over 40% in the volume of work done when compared to the original planned activities. The graphs to the left (linear approach) demonstrate that some resources (blue) are hardly used because they demand other tasks to be finished. Using resource restrictions to calculate an optimized schedule, we delay one phase of the project, represented by the use of green resources, and we can accomplish more work in less time by the blue and red teams.

Linear approach	: Green 720 hours	Red 400 hours	Blue 160 hours
Critical Chain/SDPM/Optimization:	Green 720 hours	Red 500 hours (+25%)	Blue: 260 hours (+62.5%)

In the next figure we can see five subprojects that were initially planned with dedicated resources to each phase. By reorganizing the resources in an optimized schedule, the simulation on the right demonstrates that each resource is used intensively in the project and makes it possible for new phases to have an earlier start. Here, each colour represents a different work that should be executed in a given period of time.



A simple example:

- In large buildings, we often find separate elevators for a different number of floors, so each elevator doesn't lose time by stopping at each and every floor and as in the general result we have more people transported in little time.
- The same approach is seeing here when we concentrate the available machinery to quickly finish a phase in one subproject, even when this represents a immediate delay for another subproject. The fact is that the necessary result for each subproject is achieved earlier, thus liberating the same machinery to improve the results in the following subprojects.

The challenges:

From August (time of the preparation of this text) to November of 2007 (time in which we will be presenting this paper at the PMI Global 2007 – Cancun) we expect the most intense work of the SDPM team and the other teams involved in the recently created war room. Our next milestones are:

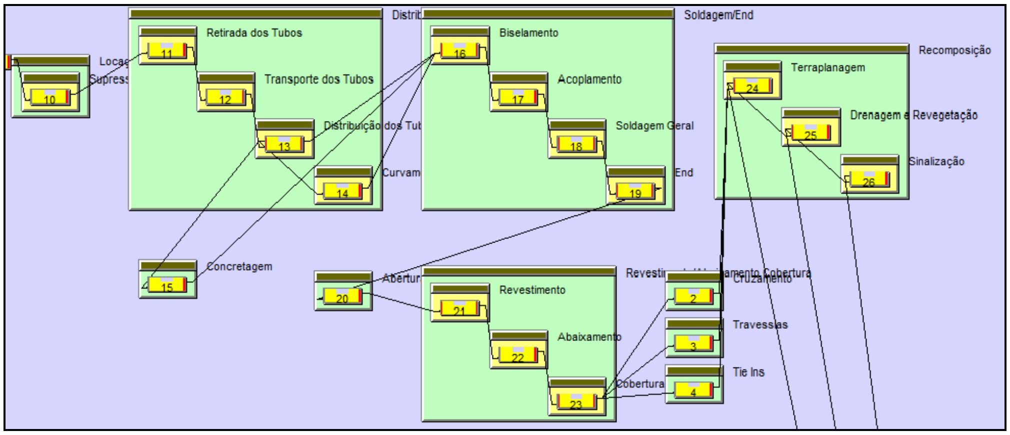
- August, 15th: Approval of the new Work Breakdown Structure for the Project, considering integrated results from several dispersed projects.
- August, 30th: Integrated data collection at each construction site. The integrated data analysis will permit the evaluation of each phase; sites may have their work stopped or reduced to transfer man power and machinery to other focused areas of the project.
- September, 25th: Optimized scheduling for all construction sites, with intense participation of functional areas, contractors and the SDPM team.
- October, 25th: Detailed resource usage registration, with increased use of Project Simulation for expanding the ability of optimizing scheduling
- November, 12th: Presentation of this paper and the achieved results to date, for the Urucu/Manaus Pipeline construction.

Project Modelling and Simulation:

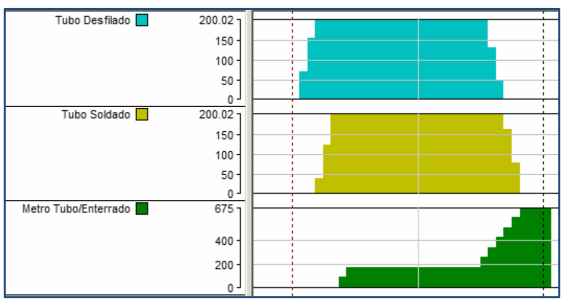
When analyzing the actual work breakdown structure for the project, we can see that we have up to seven levels of decomposition of the work. In the sixth and seventh level, the work packages are then administrated by each contractor according to their own level of detailing. With the improved work breakdown structure, the SDPM team is building a "pipeline fragnet" that will enhance the level of control of the use of each resource. A fragnet is a "piece of the network" that is specialized in one repetitive package of work for the project. The main fragnet is "1 kilometer of pipeline". This means that all the necessary (engineering) work for the construction of one kilometre is detailed to the lowest possible level. The fragnet is created using volumes and productivities instead of simply duration estimates (currently used in the project planning). Groups of fragnets are put together (10 or 20 kilometres of pipelines) and adjusted accordingly to topographic characteristics (lower or higher expected productivity due to the condition of the soil, logistics, etc). Each group of fragnets constitute new levels of details in the general project.

Present Project Planning : 5,000 lines – 7 levels of detailing in the WBS.
New Work Breakdown Structure : 30,000 lines – up to 12 levels of detailing in the WBS (with fragnets).

If we consider each necessary activity for the "fragnet", we can deploy the necessary manpower and machinery so that each team can advance one kilometer per day. As one team depends of the work done by others, the resulting "fragnet" for 1 kilometer takes from 25 to 30 days to execute the necessary activities. By organizing many "fragnets" together and optimizing the resulting schedule, it is possible to administrate several teams and then build 35 to 40 kilometers for each 35 to 40 days, giving an average speed of 1 kilometer of pipeline per day.



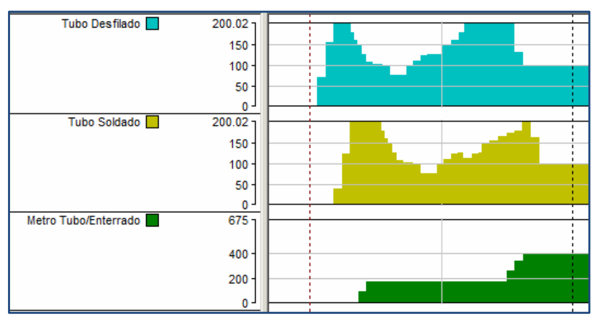
The above figure shows part of the "fragnet" with one kilometre of pipeline. Each task is organized in phases according to the WBS and all the necessary resources for its execution are calculated with the best available information (productivity of machinery and man power).



With the use of simulation and quick data collection in the field, the SDPM team may discover that some of the teams are in fact producing much less than the following teams could use to continue the work. Therefore, while some teams would be overloaded with work, others would be waiting to continue their activities. In the chart to the left each team (blue, yellow green) is in fact capable of conducting their work because the previous teams are delivering the necessary results with similar production rates.

If any of the teams have problems with logistics or machinery, the lowering of their productivity will have immediate impact in the following teams. By transferring the right resources from one team to another, we may be able to recovery overall production of the teams and thus reducing the impact of the problems identified in each phase.

In the chart to the right, while team blue had a reduction in their productivity due to problems with machinery, the yellow and green teams had a reduction of productivity simply because they did not have work to be done because of network dependencies with the blue team. Project simulation makes it possible to practice different scenarios with a set of materials, machinery and manpower before proceeding with the real changes in the field. A quick PDCA (Plan, Do, Check, Act) cycle is necessary to provide planners with good quality information for taking decisions.



The Near Future:

Information gathered by the SDPM team and organizational changes in the project has already imposed a new rhythm for the project. By the time this paper will be presented in the PMI Global 2007, Cancún, actual data extracted from the field will give the general audience a broader view of the advantages of integrating Project Portfolio Management, Success Driven Project Management and Critical Chain concepts. We shall not forget that the expansion in the level of details planned, scheduled, and controlled by the project managers with the help of the SDPM team will provide a set of learning lessons that will improve other new and ongoing projects in the region.

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For additional information on the Spider Project software package visit these Web sites:

- Portuguese: http://www.spiderproject.com.br
- English/Russian: http://www.spiderproject.ru