CPM and GANTT: The Next Step in Multi-Project Management  
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ABSTRACT

Challenge

Instead of managing a single project, we had to craft a solution that would manage hundreds of projects sharing a set of resource pools.

Solution

Develop a Project Optimizer tool using the SAS/OR® CPM procedure and display the results using the SAS/OR® GANTT procedure.

The Project Optimizer tool takes information about the following:

- Resource availability by resource profiles including information on type of resource and time period
- Resource requirements by type of resource and time period
- Start date of the projects
- Due date of the projects, with the caveat that constrained resources could influence the due dates

The Project Optimizer will then produce a schedule that can be displayed as a report or Gantt chart.

Other decisions that can be made are:

- Whether the projects can be interrupted by activity splitting
- Setting activity priorities based on a parameter in the information that is supplied
- Whether to add resources to accelerate a given project (resource-driven durations) or to eliminate resource delays of other projects due to insufficient resources

Our Graphical User Interface uses Microsoft Excel® / VBA

The logic in the tool is as follows:

- At a minimum, the tool requires at least two tasks, with duration for both tasks, a start date for the project, and precedence relationships between the tasks, i.e. which tasks need other tasks to complete before they can run
• The tool will start tasks subject to precedence constraints; i.e. a successor task will only be available to start after its predecessor tasks have finished.

• If resource requirements and availability are supplied, the tool will delay the start of tasks until resources are available and precedence constraints have been satisfied.

• If a finish date is assigned for the project, and the finish date cannot be reached, we have 3 choices for the tool:
  - Assign more resources than are currently available.
  - Allow the project to go past the defined end date.
  - Give a message and don’t produce a schedule.

• The tool also has the option of allowing activity splitting. It can schedule a minimum amount of time for someone to work on a task, and allow for interruptions after this minimum amount of time but before the end of the task. This will allow available resources to work on tasks along the resource critical path.

• The tool also has the option of specifying priorities for each activity. Higher-priority tasks will take precedence over lower-priority tasks, and can interrupt them if activity splitting is allowed.

INTRODUCTION

In this paper we outline how we used the SAS/OR ® CPM, SAS/OR ® GANTT and PRINT procedures to create a Project Optimizer that allows projects sharing a single resource pool to be scheduled. Before delving in to the specifics of the project, a brief introduction to the tools we used is in order.

The CPM procedure is a project management tool based on the Critical Path Method of scheduling. Activities are assigned times based on their precedence relationships, starting with activities having no predecessor. The critical path is determined by making a backward pass from the end of the project to the beginning. A delay in a so-called critical activity will cause the project end date to be extended. PROC CPM is able to accommodate shifts and holiday calendars and can schedule activities constrained by shared resources. This procedure uses a heuristic to find a good, feasible solution, so there is no guarantee that the span of resulting project schedules is at a minimum. The GANTT procedure works seamlessly with PROC CPM to aid in visualizing the schedules produced. PROC GANTT can compress larger charts both horizontally and vertically to produce the desired number of output pages. Both PDF and HTML among other formats are supported using the SAS ODS facility. PROC GANTT has extensive annotation capabilities for labeling charts. Primitives like text and lines can be drawn directly using a detailed annotation data set. Or a label data set can be used to similarly apply text to every activity. Options for controlling precedence line drawing are also provided. The same holiday data set provided to PROC CPM is used by PROC GANTT to differentiate holidays visually. Now we describe the project we tackled.
**CHALLENGE**

We were faced with a scheduling task in which a common resource pool is shared among large numbers of otherwise unrelated projects. Each project was being managed via Microsoft Excel® or Microsoft Project®, and resources were assumed to be unlimited. Our mission was to help our users create realistic project schedules and to get an overall handle on the number of projects, the priorities of the projects, the due dates, and the available resources. This needed to be done at both the division and corporate levels.

However, before using PROC CPM to schedule the projects, we realized that we needed a high-level view of the capabilities within the organization. To this end, we obtained a list of projects that were needed over a 3-year period. We worked with the users to learn priorities and resource requirements. We grouped the resources into seven categories, and obtained availability estimates. Our first output was a graph showing workload against availability over time.

The result for one of the resources appears below. FTE is Full-Time Equivalent, a normalized measure of one full-time employee’s work. Please note that the resource requirements exceed the available resources during certain time periods, while at other times there is a surplus of resources.

**SOLUTION**

We chose PROC CPM to more efficiently assign resources in scheduling the projects. PROC CPM is a heuristic that finds good, feasible solutions. It does not always find the most optimal solution, but provides workable results that enable projects to proceed. PROC CPM offers a multitude of scheduling features, including many options that can be used to guide the scheduling of the projects.
When identifying resources, PROC CPM allows the user to specify the available amount of different types of resources, and when they are available. Resource type is indicated in the resource data set by the OBSTYPE= keyword. A brief summary of some of the pertinent values for OBSTYPE= follows:

- **RESTYPE** allows the user to indicate whether a given resource is consumable (like raw materials) or replenishable (like human resources)
- **ALTPRTY/ALTRATE** is used to define resource pools
- **SUPLEVEL** specifies supplemental resources to be used only when an activity stands to be delayed beyond the amount given by DELAY= and ACTDELAY=. The INFEASDIAGNOSTIC keyword allows infinite supplementary resources to be used.
- **AUXRES** enables auxiliary resource relationships to be specified. An auxiliary resource is one that is required whenever the associated resource is used. A crane operator is usually an auxiliary resource for a crane.
- **RESRCDUR** is used to specify resource driven durations. This duration is derived based on the amount of work for the task and the work rate of the resource used for the task.

In the event of insufficient resources, the Project Optimizer tool lets the user determine whether lack of resource availability will be met by adding resources, extending due dates, or interrupting the process with an error message. At the same time, we can supply PROC CPM with information about the tasks in each project, the earliest times that they can start, the latest times that they can finish, task and project priority, and precedence relationships between tasks within projects. If resource requirements and availability are supplied, the tool delays tasks until both resources are available and priority and precedence constraints are satisfied.

If necessary, PROC CPM can schedule at the shift level, and can schedule around holidays. For our purposes, start and end date were sufficient, as we were looking at monthly resource availability figures.

Finally, PROC CPM allows users to split activities so that there are idle gaps during the execution of the tasks. We can specify on a task-by-task basis which activities can be split. For a given activity, PROC CPM supports two ways of controlling the splitting: either a maximum number of segments, or a minimum duration for the segments, must be specified. Activity splitting can facilitate more complete usage of available resources. This is possible either by interrupting lower priority activities or activities not on the critical path.

The CPM command we used is below:

```plaintext
proc cpm data=resource_requirements /* Activity information */
   interval=month /* Time units for activity durations */
   date="&Project_StartDate."d /* align schedule to start date */
   out=schedule /* output schedule data set */
   resin=resource_availability_update /* resource availability */
   resout=resource_usage /* usage of each resource */
   resourcesched=resource_schedule /* when each resource is used */
   suppressobswarn; /* suppress missing value warnings */

activity initiative; /* Identify activities to be scheduled */
   /* durations are resource-driven so no durations are provided */
   successor successor1-successor8; /* precedence relationships */
```
Using PROC CPM, we were able to schedule the projects within resource limitations, though the time span of the multi-project was extended by 6 months. See the figure below.

**Requirements**

*After processing through the Optimizer Tool*

*Gatekeepers*

We used PROC GANTT to display the schedule. As we allowed tasks to be split in order to avoid idle resources, the task segments are labeled “Part 1”, “Part 2”, etc. PROC CPM supplies a reserved segment number with the variable name segmt_no. This variable was not included in the Gantt chart so that it could focus on the categories of concern to the user: People, Process, Plant, and Equipment. For the
same reason, the project and task number, the task name, and the resource name are listed above the bars instead of in the column to the right.

PROC GANTT provides a wide array of options in defining charts. It allows the user to specify the time periods, the intervals (we chose quarters), the reference lines, and the colors and size of the charts. We used a parameter file as part of the input to specify the different graphical details on the Gantt chart. The PROC GANTT command and resulting chart appear below:

```sas
proc gantt data=gantt_data(where=(e_start^=.)
  rename=(start_date=e_start end_date=e_finish))
  labdata=label_E; /* labdata data set controls annotation */
chart
  e_start='' e_finish='' /* plot e_start and e_finish */
  mininterval=qtr /* time interval for labeling */
  nojobnum nolegend mindate="&Project_StartDate"d
  maxdate="&Project_EndDate"d
  /* specify key for linking label and activity data sets */
  labvar=initiative
  labsplit='|' /* specify split character */
  scale=10 /* adjust the horizontal scale of the chart */
  skip=4 /* add vertical space between bars */
  barht=.1 /* specify bar height */
  chcon=black /* specify black for horizontal connector color */
  height=1.5 /* adjust text height */
  /* collate tasks by zone */
  zone=Category onezoneval zoneoff=-1 czone=black
  /* specify reference lines */
  ref="&quarter_graph_start"d to "&quarter_graph_end"d by qtr
  cref=black lref=1 lwidth=1 idpages
  useformat; /* apply proc format to time axis */
run;
```
In order to provide the users with a summary of the changes suggested by PROC CPM, we used PROC PRINT and ODS to produce spreadsheets comparing the start and end dates before and after PROC CPM was run. The spreadsheets were generated both at the overall activity level, and at the activity-resource level.

Finally, we set up a front-end to the system using Microsoft Excel and Microsoft Visual Basic. A copy of the input screen is below. It allows the user to point to spreadsheets that contain the resource requirements, the resource availability, and the options chosen by the user:
# Scheduling Tool

## Inputs
- **Input (Relative Path)**: \`\`

## Actions
1. **Input (Relative Path)**: \`\`
2. **Step-1: Download Input Files & Save to Specified Directories**
3. **Step-2: Specify the Unit of Interval**
   - **Month**
4. **Step-3: Specify Project Start Date**
   - **1 Jan 2012**
5. **Step-4: Specify Project Completion Date** (Optional)
   - **31 Dec 2014**
6. **Step-5: Copy Parameters & Delete Existing Output Files**
7. **Step-6: Generate Output**

### Instructions
1. Update the relative path of input file and output files, if necessary.
2. Download all the necessary input files to the "Input" folder.
3. Run the tool, as instructed stepwise.
4. See output.

## Output
- **Pictorial Representation**

## Conclusion
We have demonstrated how the Project Optimizer uses the CPM and GANTT procedures to schedule a multi-project and display the corresponding Gantt chart. By making adjustments through the Project Optimizer, we were able to bring the resource usage down to acceptable limits. This did however extend the schedule an additional six months.

## References

## Acknowledgments
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