Project Planning, Uncertainty Analysis and Critical Chain Management.

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Abstract— Critical Chain Management is a relative new way of handling the variability in project schedules. The clue is to establish a chain of critical activities and chains of non-critical activities. In the chains are connected buffers to take care of uncertainty in the time plan. The management consists in deciding and watching the use of these buffers.

The sizes of the buffers are dependent of how much safety we have to, or want to build into the plan. An uncertainty analysis gives us the support we need for decisions about milestones in the plan and buffers to protect against the impact of variability.

In the following gives an example by use of Microsoft Project and a special data program for planning under uncertainty.

Index Terms—Uncertainty in scheduling, Stochastic time planning, The step-by-step process, Critical chain with buffers, Plan with last dates for outcry.

INTRODUCTION

Project planning is to make decisions about future performance.
The great challenge in all planning is that we can't know how the future will turn out, how the project surroundings and its stakeholders will react, and weather the assumptions about the external conditions for the project are reliable or not.

The forecast has the purpose to predict the future behaviour of factors that will influence the results of a project. The objective of the forecasting is to get a reliable estimate of cost or/and duration of a project. In an early stage of the project we are not interested in the details, but we are, or should be, interested in the main factors and their uncertainty.

To avoid or decrease possible effects and consequences of the uncertainty we try to make plans that cover the effects by building safety into the task duration and cost.

In many projects, however, the assumed problems we have covered up for don't strike, and there are no reasons for use of the built-in safety. Still the time and cost frames are used due to the impact of Parkinson's Law[1].

Manuscript received August 7, 2006.
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[1] Parkinson's Law: "Work expands to fill the time and cost available".

One way of thinking about how to deal with this conflict is to develop strategy to avoid expansion of time while protecting against effects from unwanted events.

In the following a management method is presented that is a combination of time planning under uncertainty and critical chain scheduling with buffer management

The procedure involves 8 steps:

1. Create a PERT chart
2. Identify internal and external influence factors
3. Add the influence into the network structure
4. Estimate activity durations
5. Work out the plan including time uncertainty
6. Decide time frames for important milestones
7. Convert to work chains with buffers
8. Develop strategy for use of the buffers

1. CREATE A PERT CHART

The example is based on a time plan of a dummy project where the activities or tasks are identified with characters.

We start with creating a Work Breakdown Structure (WBS) of the project and define predecessors and successors for every task.

In the example the tasks are named a, b ...v, while R and W are defined milestones.

From the WBS we create a structure of the project as a network, also called a PERT chart. (See fig. 1.1)

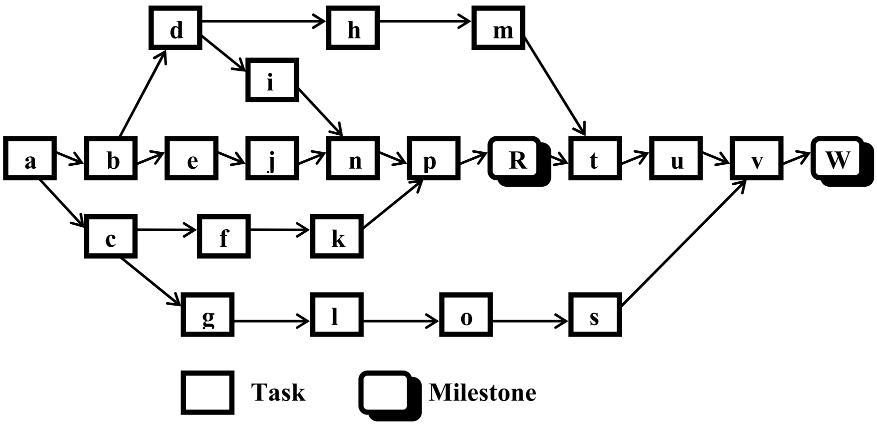

Fig 1.1 Structure plan.

2. IDENTIFY INTERNAL AND EXTERNAL INFLUENCE FACTORS

In addition to the activities in WBS there are some general issues that generate costs and consume of time. We call these issues influence factors.

These factors influence time and cost without being a defined part of the project. Internal influence factors can for instance be a lot of organizational or operational matters. External influence factors are typically political issues, finance matters, whether external conditions are reliable etc.

The exercise of bringing the influence factors and uncertainty of the project to the table is part of a process called the successive process or the step-by-step process (fig. 2.1).

The step-by-step approach is based on a systematic work procedure using a resource group to investigate the project risks and opportunities. The main idea is to be able to throw light on all sides of the project.

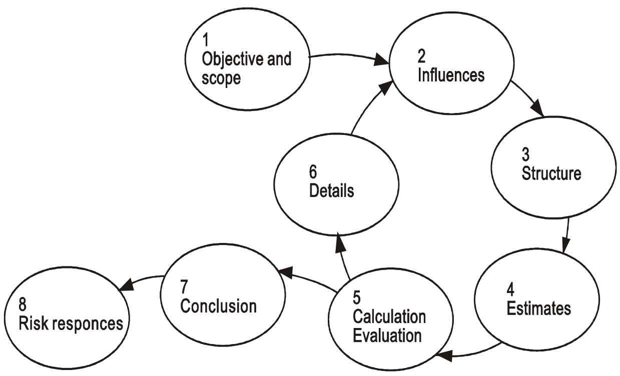

Fig 2.1 Work procedure of the step-by-step process

3. ADD THE INFLUENCE INTO THE NETWORK STRUCTURE

In figure 3.1 we have inserted influence factors Q and X. These factors are usually a grouping of keywords from a brainstorming process in the resource group. The estimated effects on the schedule are added to the structure plan subsequent to the activities they influence on, and previous to the milestone we want to protect.

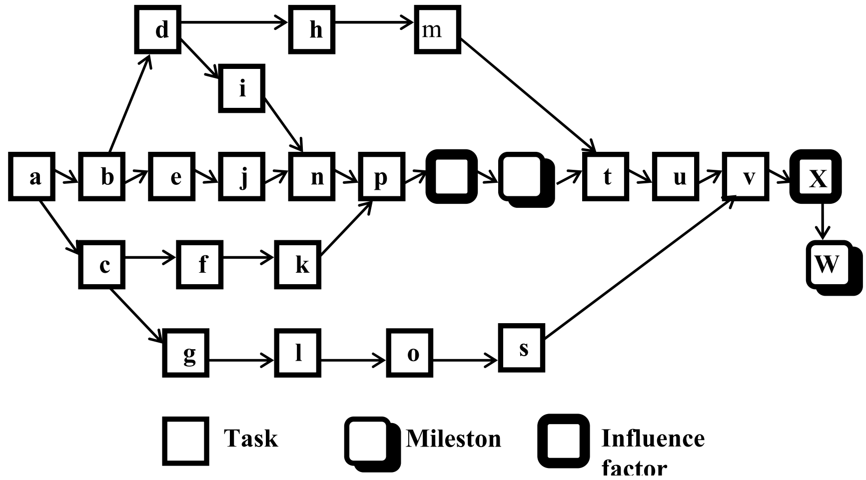

Fig 3.1 Structure plan extended with influence factors

$$E(T) = \frac{L + 2{,}9 \cdot S + U}{4{,}9} \qquad (1)$$

$$\sigma = \frac{U - L}{4{,}6} \qquad (2)$$

The variance is the square of the standard Deviation

$$VAR(T) = \sigma^2 \qquad (3)$$

To estimate these three characteristics values we have to use subjective estimation. I.e. the best estimate highly qualified people can give. The estimators have to rely on their intuition, experience, know-how and common sense.

4. ACTIVITY DURATION AS THREE-POINT ESTIMATE

Estimation is a group work. To extract the uncertainty of the estimates the duration is shown as probability distributions. We assume that duration is well represented by Erlang-distributions. To establish the distribution, the group stipulates three characteristic values on the distribution curve:

1. The lower limit (*L*), which is the 1%- quantile, (the value with only 1% chance not to be exceeded).
2. The upper limit (*U*). The 99%- quantile (the value with only 1% chance to be exceeded).
3. The most probable value (*S*). The mode of the distribution curve.

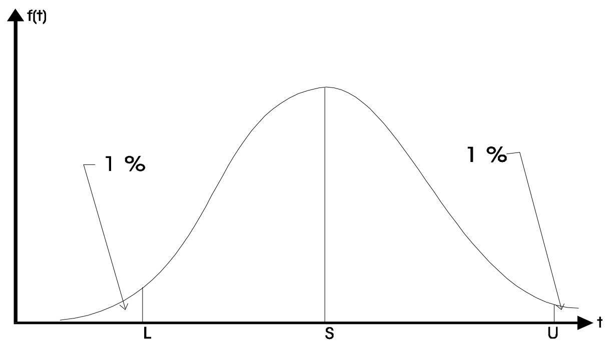

Fig 4.1 Three - point estimates of L, U and S

If we have stipulated these values correctly, we can calculate the expected value (E), and the standard deviation (σ) of the activity duration.

Table I: Estimates from the group, and results

Task	L	U	S		E	σ	Pri-ority
a	2	10	5		5.4	1.7	5
b	1	7	3		3.4	1.3	12
c	4	12	7		7.4	1.7	14
d	4	12	7		7.4	1.7	
e	3	12	6		6.4	2.0	7
f	7	16	10		10.6	2.0	
g	4	11	6		6.6	1.5	15
h	9	20	13		13.6	2.4	
i	2	7	3		3.6	1.1	
j	4	15	8		8.6	2.4	4
k	3	9	5		5.4	1.3	
l	7	22	12		13.0	3.3	10
m	6	18	9		10.2	2.6	
n	7	20	12		12.6	2.8	3
o	10	25	14		15.4	3.3	9
p	6	15	10		10.2	2.0	6
Q	0	15	4		5.4	3.3	1
R	0	0	0		0	0	
s	8	19	12		12.6	2.4	13
t	3	10	5		5.6	1.5	11
u	5	13	8		8.4	1.7	8
v	2	5	3		3.2	0.7	
X	0	12	3		4.2	2.6	2
W	0	0	0		0	0	

The column "Priority" ranks the tasks after their influence to the uncertainty of the milestones. The priority tells us which tasks that require our attention. Priority 1 is the most important. The list is a result from the calculation of the critical index (KI) from fig. 5.1) and the standard deviation of duration of each task from the estimation process. Critical index of a task is the probability in % to become critical.

5. The step-by-step process until acceptable plan

In this example the structure plan and the duration estimates are input in a computer program. The step-by-step process is used until the result is acceptable. Figure 5.1 shows the final result.

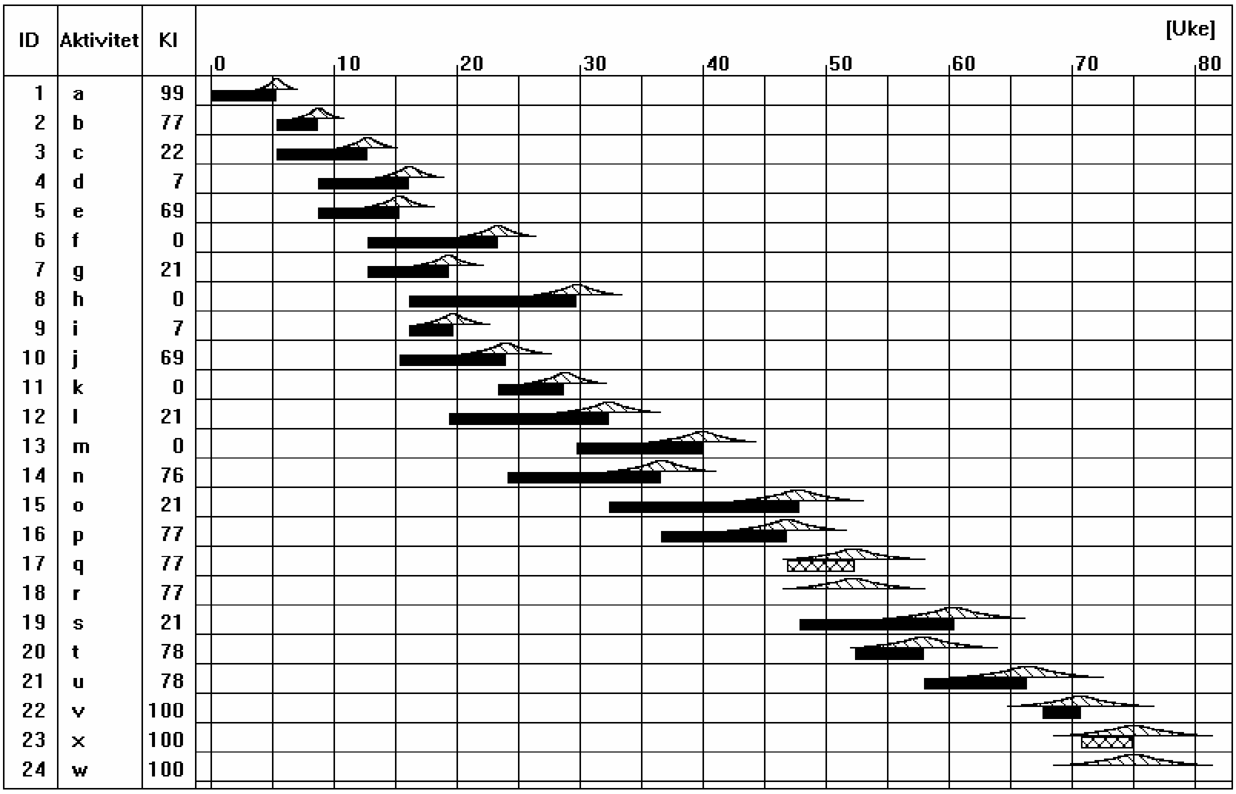

Fig 5.1 Gantt-chart with deviation of the finish time for the tasks. (Aktivitet = Activity (task), KI = critical index, Uke = Week)

6. Analysis of the plan, and decisions about important milestones

The results from the process are shown in fig. 5.1, and we decide milestone (R) to be 52 weeks after project start, and finish time, milestone (W), 75 weeks after project start.

The criticality index, KI, points out the most critical path. In our case it contains following activities and milestones: a,b,e,j,n,p,Q,R,t,u,v,X and W, with critical indexes from 69 % to 100 %.

The second most critical path is the chain a,c,g,l,o,s,X and W, where the “new” KIs are from 21 % to 22 %.

These two chains meet at the start of task (v), (see fig. 3.1), and as a curiosity we see that the simulation shown in fig. 5.1 has made a gap of time between end of task (u) and start of task (v). This gap is a stochastic time-addition, and is a function of number of chains meeting in one point, and the probability of the chains to be critical.

7. Convert the plan to a control reference

Stochastic methods for time planning (scheduling) are very useful for analysis of risk and uncertainty in the schedule, and make us able to build safety into the plan.

A stochastic plan, however, is not very suitable for day to day management of the project.

By transforming the stochastic plan into a plan with a chain of high-critical tasks and chains of low -critical tasks, and convert the uncertainty addition from each task to buffers in order to protect the milestones, we create a plan that is fit as an instrument for management during the project performance.

We will in the following give an example of how to make a plan of critical chains (fig. 7.1).

- Go back to the start PERT network (fig. 1.1 without influence factors) and use most probable values (*S*) as duration estimates.
- Fix the milestone schedule, and the Gantt plan as a baseline.
- Arrange the plan with the most critical path in the middle, and the less-critical chains on both sides.

ID	Task Name	Duratior
1	d	7 wks
2	h	13 wks
3	m	9 wks
4	i	3 wks
5	a	5 wks
6	b	3 wks
7	e	6 wks
8	j	8 wks
9	n	12 wks
10	p	10 wks
11	R	0 wks
12	t	5 wks
13	u	8 wks
14	v	3 wks
15	W	0 days
16	c	7 wks
17	f	10 wks
18	k	5 wks
19	g	6 wks
20	l	12 wks
21	o	14 wks
22	s	12 wks

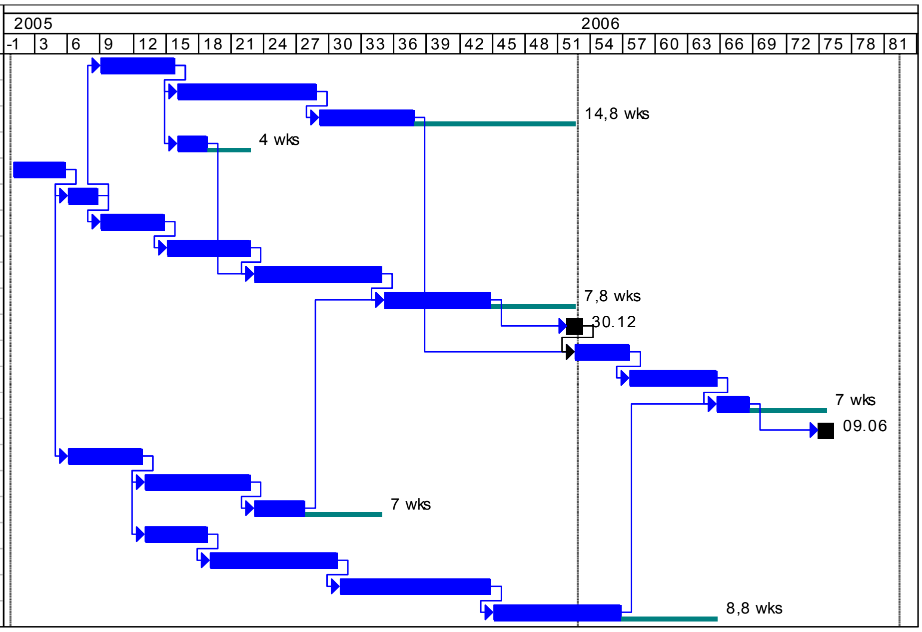

Fig 7.1 Rearranged plan with work chain

- Replace free float on most critical path with so-called Project Buffers. We have now established the critical chain (Fig. 7.2).
- Replace free float on the less-critical chains with so-called Feeding Buffers (Fig. 7.2).

ID	Task Name	Duration
1	d	7 wks
2	h	13 wks
3	m	9 wks
4	Feeding Buffer3	15 wks
5	i	3 wks
6	Feeding Buffer 1	4 wks
7	a	5 wks
8	b	3 wks
9	e	6 wks
10	j	8 wks
11	n	12 wks
12	p	10 wks
13	Project Buffer 1	8 wks
14	R	0 wks
15	t	5 wks
16	u	8 wks
17	v	3 wks
18	Project Buffer 2	7 wks
19	W	0 days
20	c	7 wks
21	f	10 wks
22	k	5 wks
23	Feeding Buffer 2	7 wks
24	g	6 wks
25	l	12 wks
26	o	14 wks
27	s	12 wks
28	Feeding Buffer 4	9 wks

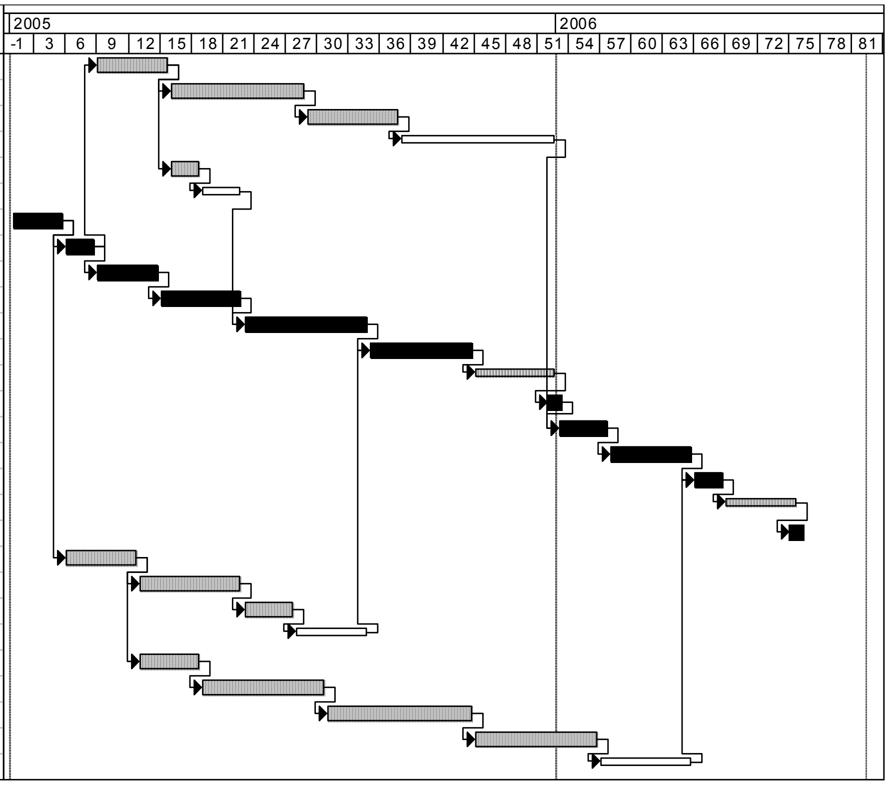

Fig 7.2 Critical chain with buffers

8. Strategy for use of the buffers

The purpose of the buffers is to protect the milestones. There are hundreds of well approved books and articles that describe buffer management and the topic will not be further discussed in this paper. However, to keep control, you often need an overview over the deadlines for outcry to avoid crises. Suitable for this purpose is to distribute the buffers on the tasks, and thereby establish a deadline for start or finish of each task in the schedule.

What should be the distribution formula? Tasks with high uncertainty need more buffer than tasks with low uncertainty, and crises are a consequence of worst case occurrence.

We will in this case use worst case approach, and the maximum values (*U*) from the three-point estimates as distribution formula.

The result is shown in fig. 8.1 as last dates for outcry of a delay that will jeopardize the milestones.

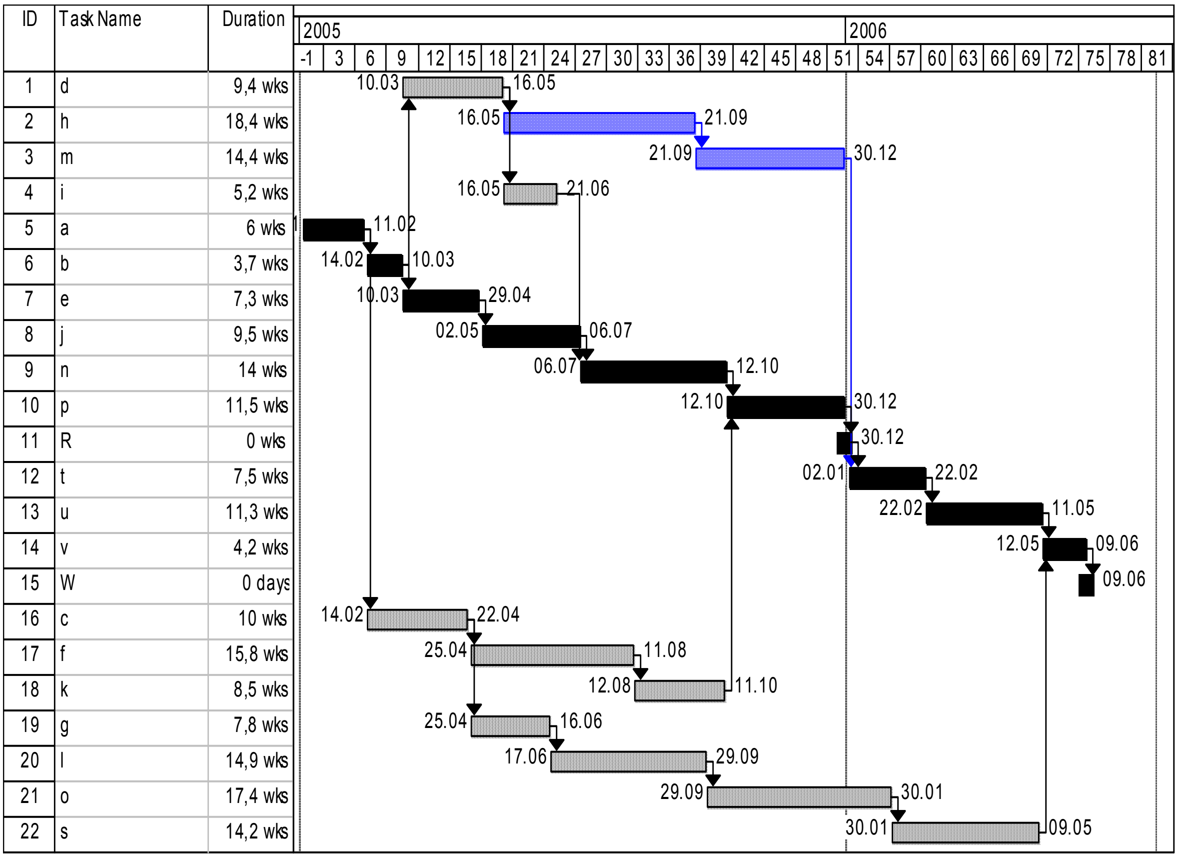

Fig 8.1 Plan with last dates for outcry.

9. Conclusion

Stochastic time planning involves uncertainty analysis to find influence factors, and task durations given as probability distributions. Stochastic plans are not useable as work schedules, but the results give basis for work plans, as for example critical chains.

Critical chain management is discussed in a great number of well approved books and articles, and in this paper the subject is limited to deal with latest time for outcry to avoid crises due to time overruns.

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