Estimate accuracy and causes of delay in an engineering research laboratory

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Abstract. Some of the main results of a study of the accuracy of cost and duration estimates in this laboratory have already been published. This short article adds some further information about the accuracy of duration estimates for stages of projects (as opposed to whole projects), and about the reasons for upward revisions of duration estimates.

THE RESEARCH ORGANIZATION AND THE DATA

A previous article in *R & D Management* (Norris, 1971) gave the results of retrospective studies of the accuracy of project cost and duration estimates, based on data collected from four varying research organizations. In one of these studies (RDU 4), the records provided duration estimates for parts of projects, as well as for whole projects, and also information about the reasons for upward revisions of duration estimates. These have enabled some additional kinds of analysis to be made for this set of 50 completed projects.

The organization concerned is a medium-sized commercial laboratory, doing work on large and complex engineering products, in which many of the components and sub-systems have to meet very exacting specifications. Research is closely linked to design, and many projects arise from the design side of the company, when available technical information is found to be inadequate for the work in hand. The projects are contributions to development, rather than developments in themselves, and have an average cost of £7,600 and an average duration of ten months. They are fairly homogeneous in structure, and can therefore usually be regarded as a sequence of the following five stages, omitting (1) and (2) if they have been covered by previous work.

1. Procuring and setting up experimental equipment.
2. Proving experimental equipment and techniques.
3. Main experimental programme.
4. Analysis of results.
5. Writing of report.

Estimates of cost are made once only, for the whole project, but estimates of duration are made for individual stages, and are revised at regular intervals. Similarly, completion dates are recorded for individual stages. When a revision is made, and a later date is given for the completion of a stage or stages, the reason for the delay is usually recorded. For the purpose of the present analysis, the estimated duration of a whole project is taken as the sum of the initial estimates for the stages. The estimated duration of an individual stage, however, is not the initial estimate, but the last estimate made before the stage was started.

ACCURACY OF ESTIMATES

For whole projects, the mean ratios of actual to estimate are 1·16 for cost, and 2·38 for duration. These values fall within the ranges found for the other three organizations, and are also similar to them in showing a much greater degree of optimism in estimating duration than in estimating cost. The variation of the individual project ratios about their means is shown in frequency distributions (Figs. 1A and 2) given in the earlier article.

The ratios of actual to estimated duration for the project stages are given in Table 1. Although the estimates for the later stages had the benefit of information gained in the earlier ones, there is no evidence that this made them more accurate. The mean ratio for Stage 4 is low, but the mean ratio for Stage 5 is the highest of all. Similar conclusions about the failure of estimates for the future parts of projects to improve as the projects progress were also reached in the other three studies, though on the basis of a different form of analysis.

Table 1. Accuracy of Stage Duration Estimates

Stage	*Number of of estimates*	*Mean estimated duration (months)*	*Mean ratio of actual to estimated duration*
1. Procuring equipment	39	1·2	1·94
2. Proving equipment	44	1·1	1·80
3. Main experiments	47	1·4	2·19
4. Analysis	43	0·8	1·30
5. Report	47	1·6	4·05

Since Stage 5 not only has the highest mean duration ratio (4·05), but also the highest mean estimated duration, it makes a substantial contribution to the whole-project duration ratio (2·38), without which this ratio would be about 2. These high ratio values are to some extent misleading, however, as indications of the performance of the laboratory, since it is known that the main results of a project were very often communicated informally to those who needed them at the end of Stage 4, so that the completion of the report, though still necessary for future reference, was no longer a matter of urgency.

CAUSES OF DELAYS

In all four studies, costs were mainly for manpower. The much higher values of the mean duration ratios, compared to the mean cost ratios, therefore suggested the inference that the main reason why actual duration exceeded estimated duration was not an unexpected increase in the amount of work required, but rather delays caused either by the competition of other projects for manpower, or by external causes such as late delivery of equipment or lack of access to special facilities or

services. In the present study, this inference is confirmed by the analysis of the reported causes of delay, the results of which are given in Table 2.

The relative importance of the groups of causes is shown both in terms of the number of occasions on which they were reported, and of their percentage contribution to the total time lost through delays. Unexpected technical difficulties—some of which, such as equipment failures or inadequacies, did not necessarily involve additional work within the projects—accounted for only a third of total delays. The remainder was accounted for mainly by lack of manpower (due to the competition of other projects), and by failure to obtain equipment or services at the required time from sources external to the projects. The delays due to need for further tests, to lack of engineer manpower (i.e. people in charge of projects being otherwise occupied) and to late delivery of equipment, are shown separately because they were the three largest single causes of delay for whole projects.

Table 2. Causes of Delays

Whole Projects

Cause of delay	*Number of occasions*	*% of total delay time*
Unexpected technical difficulties		
Need for further tests	19	14
Other technical problems	32	16
	51	30
Lack of manpower		
Engineer in charge	11	18
Other manpower	14	9
	25	27
Awaiting supplies and services		
Late delivery of equipment	18	11
Other	18	13
	36	24
Awaiting decisions	6	7
No reason given	12	11

Stages of Projects

Stage	*Main cause of delay*
1. Procuring equipment	Late delivery of equipment
2. Proving equipment	Late delivery of equipment
3. Main experiments	Need for further tests
4. Analysis	Need for further tests
5. Report	Lack of engineer manpower

The main causes of delay at stages of projects were late delivery of equipment at Stages 1 and 2, need for further tests at Stages 3 and 4, and lack of engineer manpower at Stage 5.

OTHER FINDINGS

To look for possible effects of project length on the accuracy of estimates, the 50 projects were divided into 18 longer ones, with a mean estimated duration of 6·4 months, and 32 shorter ones, with a mean estimated duration of 3·2 months. Unexpectedly, the mean estimated cost was less for the larger projects, implying that the shorter ones had a much greater intensity of effort. The shorter projects were found to have a lower mean ratio of actual to estimated cost (1·03, against 1·11), but a higher ratio of actual to estimated duration (2·50, against 2·17), though the latter can be accounted for entirely by a higher ratio at the report stage.

Finally, a comparison was made between more recent and less recent projects, in order to detect any changes in the general level of estimate accuracy. In the other studies, there was no evidence of such a charge, but in the present one there was a definite improvement. The mean cost ratio for 28 more recent projects was 0·94, against 1·23 for 22 less recent ones, and the mean duration ratio was 2·05, against 2·88. Lower mean duration ratios were found at four of the five stages, but the overall improvement was mainly due to the large improvement at the report stage. The reason for these improvements is not known for certain, but in the opinion of the management the most likely contributory factors are better project definitions (arising from improved definition procedures), the occurrence of a number of urgent but relatively small and self-contained projects, and an easing off in the total laboratory workload.

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REFERENCE

Norris, K. P. (1971) 'The accuracy of project cost and duration estimates in industrial R & D', R & D Management, Vol. 2, No. 1 (October), p. 25.