DETERMINING SCHEDULE IMPACT: WORKING PRACTICE

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ABSTRACT: Construction project delays may result from many circumstances. Negotiating a fair and timely damage settlement is beneficial to all parties. Network-based scheduling is an excellent way for negotiating settlement of changes, disputes, and delays throughout the project. In the construction industry, however, there is no single standard and no "accepted" procedure to determine impact of schedule delays. This paper suggests a practice for evaluating schedule impact. The practice allows available float to be shared by both the owner and the contractor.

INTRODUCTION

Due to the many sources and causes of construction delays, it is often difficult to analyze the ultimate liability in delay claims (Kraiem and Diekmann 1987). In recent years, the use of network scheduling techniques in evaluating the validity of requests for time extensions has proven beneficial. Network-based scheduling has developed into an excellent way for negotiating timely settlement of changes, disputes, and delays throughout the life of a project.

The majority of risk associated with the profit or loss of a construction project rests with the lump sum prime contractor. It is he who stands to gain or lose financial profit (as well as reputation). The contractor must complete the project in a timely manner and, he hopes, with as little outside interference as possible. Schedule float belongs to the project; however, inordinate control of project float by either party should necessitate a change in the original contract conditions. And when the owner has substantially contributed to a delay some U.S. Courts have refused to apportion delays. The reasoning is that substantial contribution to the delay (by the owner) alters the terms of the contract (Callahan et al. 1992).

This paper suggests a practical way of determining schedule impact. This assessment of delay (in days) is valuable to project managers because it becomes a basis for calculating financial penalties or other damages.

SCHEDULE IMPACT METHODOLOGIES

There are several methods offered in construction literature that are considered professionally acceptable for determining the schedule impact resulting from project delays and interruptions (most often, change orders). These are the As-Planned Method (U.S. Veterans Administration); the As-Built Method (traditional); the Modified As-Built Method (U.S. Corps of Engineers); the Float Allocation Method (U.S. Board of Contract Appeals); and the Concurrent delay method.

However, there is no single, standard procedure to determine the impact of schedule delays due to change orders and other unplanned developments. Different procedures could certainly lead to varying results in the amount of time a party has been impacted. This is due to the unique calculations required by each method. The outcomes of delay analysis are often not predictable, and one method may not easily be used every time over another. The methodologies can produce varying results, depending upon many things, one of which is the logic employed by those performing the analysis (Bubshait and Cunningham 1998). To illustrate the suggested practice, a case study will be used

Case Study

The same case study discussed by Bubshait and Cunningham (1998) is used here to illustrate the suggested method. The project is a commercial facility. In general, the facilities are described as two large multi-story administration/office buildings, "C" and "P" (Fig. 1), and two warehouses of considerable size, with multi-story administration areas. The value of the facility is about $35,000,000. The project schedule is a CPM (critical path method) diagram consisting of Revisions 00, 01, and 02, each made up of over 550 activities. The following are six delays caused by the owner of the construction project:

1. Demolition and reinstallation of HVAC ductwork. During the construction of buildings C and P, it was discovered that the clearance in the hallway between the bottom of the A/C duct and the floor was insufficient. These main trunklines are very large, and when they had been installed as originally designed, there was not enough room for a person to walk underneath them. When this was discovered the mechanical (air conditioning) design firm, located in Europe, redesigned the system (re-sized the ductwork). Meanwhile, the construction contractor demolished what had already been installed. After design of the new HVAC system and approval of the plans by the client, the construction contractor was able to begin fabricating and installing the new ducts.

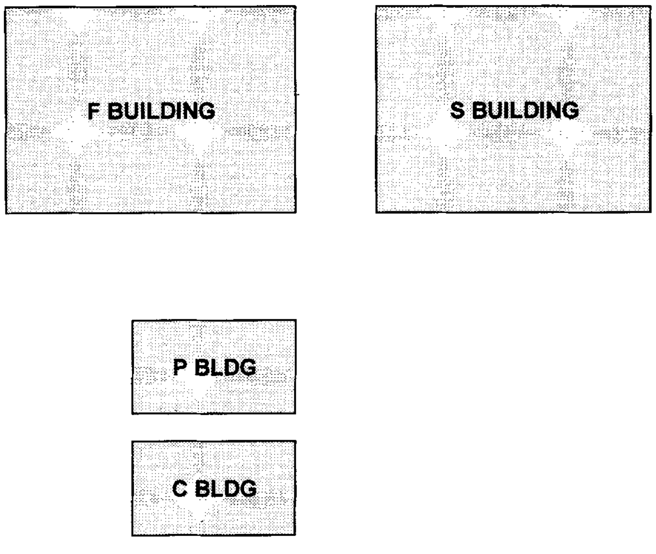

FIG. 1. Site Layout

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Note. Discussion open until April 1, 1999. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on May 15, 1998. This paper is part of the *Practice Periodical on Structural Design and Construction*, Vol. 3, No. 4, November, 1998. ©ASCE, ISSN 1084-0680/98/0004-0176–0179/$8.00 + $.50 per page. Paper No. 18343.

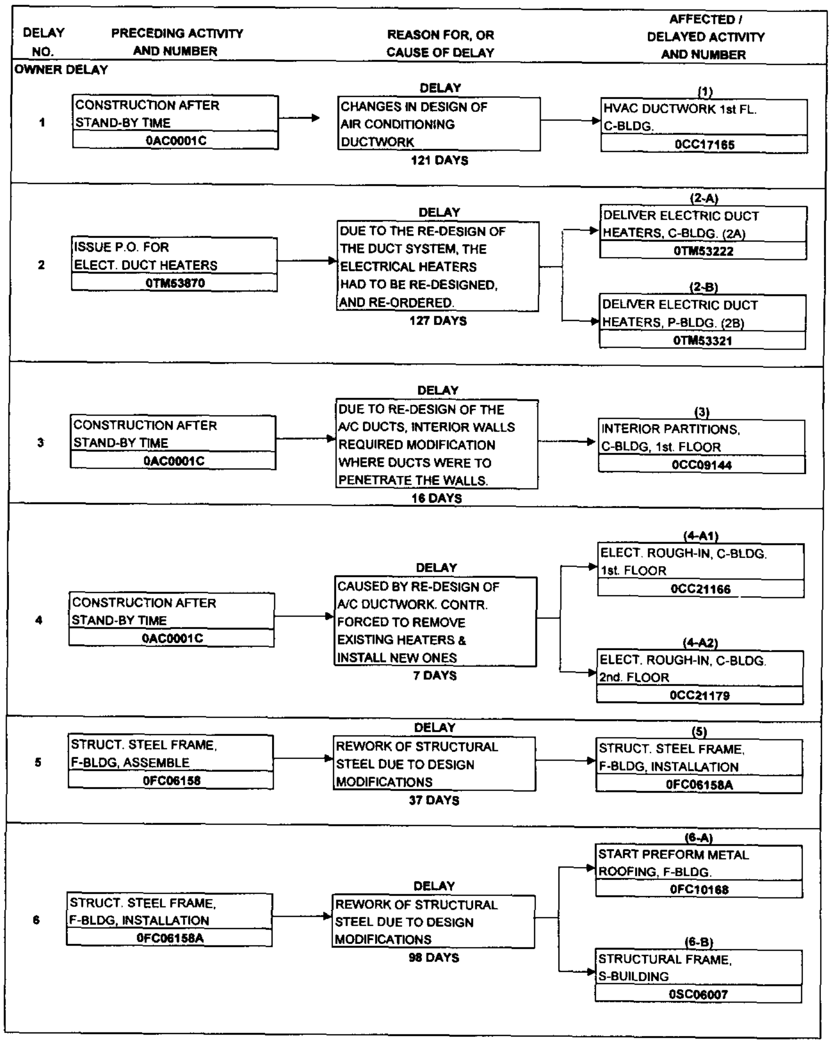
2. Late delivery of duct heaters. After re-sizing the ductwork, the originally specified duct heaters were no longer acceptable. They needed to be redesigned and reordered. These electrical devices were not available in Saudi Arabia, and thus needed to be ordered from the United States. The long lead time associated with out-of-Kingdom procurement, resulted in a delivery date which was well behind the originally-scheduled installation date. This resulted in delay of installation for buildings C and P.
3. Modification of interior partitions. As a direct result of the re-sizing of the air-conditioning ductwork, some of the interior concrete block walls required modification. The duct system was designed with the A/C supply boxes entering the rooms through pre-positioned "holes" in the walls. These "holes," or block-outs, were to be located high up the walls, above where the suspended ceiling would be installed. The building contractor had to "re-position" most of the duct blockouts where the walls had already been constructed, on the first floors of building C and P.
4. Rework of electrical wiring. As a result of the redesign of the duct heaters, the HVAC design firm also changed many of the locations of the duct heaters. By moving the duct heaters, the electrical conduit that had already been installed needed to be changed. The building contractor removed that which was no longer usable. This removal was required on parts of all four floors of the C building.
5. Reinstallation of structural steel. The structural steel main trusses of the F building had been installed according to the approved construction drawings. Due to the high winds experienced in the Eastern Province of Saudi Arabia, it is customary for large structures to undergo a three-dimensional stress analysis. The result of the study indicated that the building design was undersized.
6. Rewelding of structural steel. During the assembly and installation of the structural steel components, random testing of the welds was conducted. Testing was conducted using x-ray procedures. Although the welding had been performed according to specifications, the results indicated that some of the welds did not completely penetrate the adjoining sections of steel. In order to ensure that the structure was joined soundly, all of the welds were individually inspected, and many of the joints required additional welding for strength. This delay further impacted construction progress in buildings F and S.

Bubshait and Cunningham (1998) used three different methods to analyze the case study. The findings were a 56-day delay for the As-Planned Method, a 58-day delay for the As-Built Method, and a 208-day delay for the Modified As-Built Method.

THE SUGGESTED PRACTICE

The suggested practice is presented as a set of points:

1. The As-Planned schedule, which was submitted and approved by responsible parties, is required. The progress



DELAY NO.	PRECEDING ACTIVITY AND NUMBER	REASON FOR, OR CAUSE OF DELAY	AFFECTED / DELAYED ACTIVITY AND NUMBER
OWNER DELAY			
1	CONSTRUCTION AFTER STAND-BY TIME 0AC0001C	DELAY CHANGES IN DESIGN OF AIR CONDITIONING DUCTWORK 121 DAYS	(1) HVAC DUCTWORK 1st FL. C-BLDG. 0CC17165
2	ISSUE P.O. FOR ELECT. DUCT HEATERS 0TM53870	DELAY DUE TO THE RE-DESIGN OF THE DUCT SYSTEM, THE ELECTRICAL HEATERS HAD TO BE RE-DESIGNED, AND RE-ORDERED. 127 DAYS	(2-A) DELIVER ELECTRIC DUCT HEATERS, C-BLDG. (2A) 0TM53222 (2-B) DELIVER ELECTRIC DUCT HEATERS, P-BLDG. (2B) 0TM53321
3	CONSTRUCTION AFTER STAND-BY TIME 0AC0001C	DELAY DUE TO RE-DESIGN OF THE A/C DUCTS, INTERIOR WALLS REQUIRED MODIFICATION WHERE DUCTS WERE TO PENETRATE THE WALLS. 16 DAYS	(3) INTERIOR PARTITIONS, C-BLDG, 1st. FLOOR 0CC09144
4	CONSTRUCTION AFTER STAND-BY TIME 0AC0001C	DELAY CAUSED BY RE-DESIGN OF A/C DUCTWORK. CONTR. FORCED TO REMOVE EXISTING HEATERS & INSTALL NEW ONES 7 DAYS	(4-A1) ELECT. ROUGH-IN, C-BLDG. 1st. FLOOR 0CC21166 (4-A2) ELECT. ROUGH-IN, C-BLDG. 2nd. FLOOR 0CC21179
5	STRUCT. STEEL FRAME, F-BLDG, ASSEMBLE 0FC06158	DELAY REWORK OF STRUCTURAL STEEL DUE TO DESIGN MODIFICATIONS 37 DAYS	(5) STRUCT. STEEL FRAME, F-BLDG, INSTALLATION 0FC06158A
6	STRUCT. STEEL FRAME, F-BLDG, INSTALLATION 0FC06158A	DELAY REWORK OF STRUCTURAL STEEL DUE TO DESIGN MODIFICATIONS 98 DAYS	(6-A) START PREFORM METAL ROOFING, F-BLDG. 0FC10168 (6-B) STRUCTURAL FRAME, S-BUILDING 0SC06007

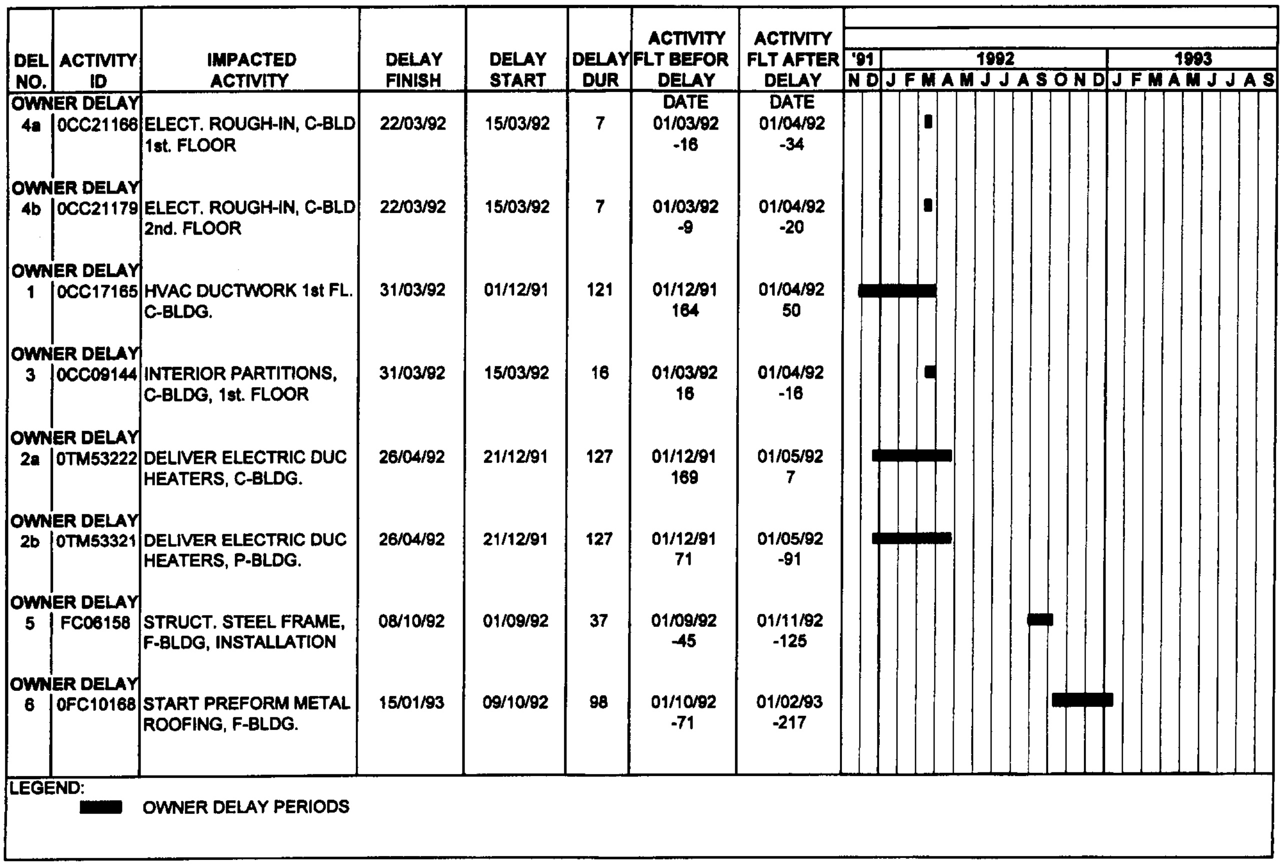
FIG. 2. Network Schedule (All Delays)

updates are also required. If the As-Built schedule is not available, or was not conscientiously statused and updated at regular (monthly) intervals, it must be reconstructed from progress reports and other available project data. To reconstruct the As-Built schedule is a time-consuming process, but necessary (for accuracy) in the delay analysis process. Only by comparison of the As-Planned with the As-Built schedules, can the effect of delays, change orders, etc., be easily recognized.

2. There usually exists a list of actions, non-actions, or other grievances among parties that require further examination, otherwise there would be no need to continue the analysis process. These instances need to be itemized by a responsible party and examined in the light of the As-Planned versus As-Built schedule results. This will assist in determining whether or not actual impact occurred, and if so, to quantify each disturbance. In other words, a delay that occurs out of the originally planned sequence may not be compensable if the contractor accelerates the work knowing that, for example, the owner-supplied material to support that effort will arrive late.

   Those change orders and/or delays requiring research can be verified through the project records/meeting minutes, etc. These sources normally furnish enough data to establish when the disturbance started, the duration, and the end date. Instances of concurrent delay require separate handling.
3. Periods of concurrent delay should be examined for cause, responsible parties, start date and duration, as well as end, for each of the overlapping delays. Concurrent delays are apportioned to each party.
4. Overlay the As-Built to the As-Planned schedule to determine exactly which activities have been affected. The contemporaneous CPM schedule contains the necessary logic to establish the sequential relationships. Having done the comparisons, short networks (or fragnets) can be created to incorporate the delayed activities (Fig. 2).
5. Owner-caused delays are highlighted and listed in order of early finish/early start. This order is recommended because delays are normally considered/analyzed for schedule impact after they have ended, not as they begin. After the first analysis the second delay is considered, and so forth (Fig. 3).
6. Monthly progress reports are relied upon to determine the progress gained during each update period. With this information, computerized calculations will determine the available float of each impacted activity, immediately prior to the start of the delay. This point in time is usually the end of the month immediately preceding the delay.

   However, it might be argued that if a delay had actually begun on the tenth day of a month, but the point of calculation is the last day of that month, the float available for that activity at the month's end may not be the same as the amount of float available on the 10th. Why not interpolate, for better accuracy? It is the opinion of the writers that the results provided by interpolation may not necessarily be any more accurate. When interpolating, one must assume that progress was achieved at a *linear* rate. Unless job records verify exact crew work locations and tasks performed during these periods, daily activity cannot be verified. Many daily construction reports list the number of craftsmen on the site each day, but rarely do they show the exact piece of work performed throughout the day. Over a month's time, construction crews often work in different areas. A crew sometimes stops in the middle of one activity, in order to "crash" another. So interpolation, although considered, will not be employed in this study.
7. Only owner-caused delays are considered in this suggested practice, except in situations of concurrency. The



DEL NO.	ACTIVITY ID	IMPACTED ACTIVITY	DELAY FINISH	DELAY START	DELAY DUR	ACTIVITY FLT BEFOR DELAY DATE	ACTIVITY FLT AFTER DELAY DATE
OWNER DELAY 4a	0CC21166	ELECT. ROUGH-IN, C-BLD 1st. FLOOR	22/03/92	15/03/92	7	01/03/92 -16	01/04/92 -34
OWNER DELAY 4b	0CC21179	ELECT. ROUGH-IN, C-BLD 2nd. FLOOR	22/03/92	15/03/92	7	01/03/92 -9	01/04/92 -20
OWNER DELAY 1	0CC17165	HVAC DUCTWORK 1st FL. C-BLDG.	31/03/92	01/12/91	121	01/12/91 164	01/04/92 50
OWNER DELAY 3	0CC09144	INTERIOR PARTITIONS, C-BLDG, 1st. FLOOR	31/03/92	15/03/92	16	01/03/92 16	01/04/92 -16
OWNER DELAY 2a	0TM53222	DELIVER ELECTRIC DUC HEATERS, C-BLDG.	26/04/92	21/12/91	127	01/12/91 169	01/05/92 7
OWNER DELAY 2b	0TM53321	DELIVER ELECTRIC DUC HEATERS, P-BLDG.	26/04/92	21/12/91	127	01/12/91 71	01/05/92 -91
OWNER DELAY 5	FC06158	STRUCT. STEEL FRAME, F-BLDG, INSTALLATION	08/10/92	01/09/92	37	01/09/92 -45	01/11/92 -125
OWNER DELAY 6	0FC10168	START PREFORM METAL ROOFING, F-BLDG.	15/01/93	09/10/92	98	01/10/92 -71	01/02/93 -217

LEGEND:
▬ OWNER DELAY PERIODS

FIG. 3. Suggested Method

DELAY		FLOAT		
NO.	DUR.	PRIOR	AFTER	POSITION
4a	7	- 16	- 34	Activity negative float has increased. Penalty is only 7 days, the duration of the delay.
4b	7	- 9	- 20	(Same position as 4a above)
1	121	164	50	Activity float remains positive - no damages.
3	16	16	- 16	Float decreased. Penalty of16 days observed.
2a	127	169	7	Activity float remains positive - no damages.
2b	127	71	- 91	Liability of 91 days. Although the actual delay duration is 127 days, impact on project completion is only 91 days.
5	37	- 45	- 125	Liability of 37 days. Although activity negative float increased from 45 to 125 days, only 37 days is attributed to actual delay.
6	98	-71	- 217	Liability of 98 days, the duration of the delay.

FIG. 4. Results of Analysis

writers feel that the lump sum contractor has the responsibility to construct the project according to his methods, implementing his own plans. Therefore only interferences by the owner are calculated. Delays in excess of those attributed to the owner fall into the contractor's area of responsibility. However, concurrent delays are apportioned to both parties. After each owner-caused delay has been analyzed, they are input to the network as activities, with the duration equal to that of the delay period. The schedule is calculated after each delay is entered. Where concurrent delay exists, the contractor's delay is also input as an activity. Periods of delay overlap are highlighted.

Fig. 3 displays network fragnets of how each delay is inserted into the schedule. Fig. 4 shows the results and the recommended positions. The number of days attributed to owner = 256 days (7 + 7 + 16 + 91 + 37 + 98). Total project delay as determined by CPM analysis/computation is 217 days. However, the sum of the individual delays totals 256 days. It is apparent that the contractor recovered 39 days (i.e. reduced overall project slippage by 39 days).

The advantage of the suggested practice is that it allows available float to be shared by both the owner and the contractor. It has been mentioned previously that if project float is used inequitably by a single party (owner, for example) the terms of the contract should be revised. Evidence of this situation was not apparent. Due to inefficiency, etc., the contractor delayed his progress as revealed in the displayed scenarios. The party who requires float first should have access to it. When project completion is affected due to any critical delay, the aberrant party should receive the penalty.

SUMMARY AND CONCLUSIONS

It is often difficult to analyze the ultimate liability in delay claims, due to the many sources and causes of construction delays. However, network-based scheduling has developed into an excellent means for negotiating timely settlement of changes, disputes, and delays throughout the life of a project. There are five accepted methods for delay analysis; however there is no single, standard procedure to determine the impact of schedule delays. Different procedures can certainly lead to varying results. This study suggests a practice for determining schedule impact. The advantage of the suggested method is that it allows available float to be shared by both the owner and the contractor.

ACKNOWLEDGMENTS

The writers appreciate the support of the King Fahd University of Petroleum and Minerals during the course of the study.

APPENDIX. REFERENCES

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