Benchmarking As-Built Lags

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Introduction

According to Section 10.1 of the AACE International Total Cost Management Framework, "Project performance assessment is the process of comparing actual project performance against planned performance and identifying variances from planned performance."[1] Performance assessment is a cornerstone of managing and controlling the project.

A lot has been said about benchmarking activity durations but little about relationships. How do as-built relationships compare to the plan? This topic has not been addressed in a serious manner. Any mention of as-built relationships in the surveyed literature refers to documenting schedule relationship changes, not assessing the performance of the relationship.[2] Perhaps a historical look at the foundations of schedule network analysis can shed some light on the subject.

Reporting Relationship Performance

Arrow diagramming method (ADM) is a critical path network (CPM) [3] diagramming system that does not use additional relationship structures[1].[4] Instead the various activities are related to each other directly by sharing the second half of the predecessor activity's ID with the first half of the successor activity's ID. For example, activity 100-110 is the immediate predecessor to activity 110-120, as they both share the 110 ID from their common node. There are no 'lags' because all of the relationships are incorporated into the coding structure. If a time lag is required between activities (such as concrete curing), then an activity is inserted that represents that time.
With an ADM activity representing the planned curing time, a later comparison of planned versus actual durations is simple and straightforward. Was the required time taken or is the cracking currently being witnessed on footings due to cutting short the curing process and building the walls too soon? A simple activity duration variance report will quickly reveal the answer.

With a precedence diagramming method (PDM) network, such questions about planned versus actual durations are much more difficult to answer. This is because required time lags between activities are typically described using relationships with lags. Analysis of planned versus actual

[1] ADM does have a zero-duration activity called a *dummy* that acts like a relationship. This is used to overcome the technical limitation caused by activity IDs substituting for relationship information with parallel activities.

lags is difficult to obtain because most CPM software companies do not include a relationship variance report in the collection of their software features.

Perhaps this industry-wide oversight is partly due to the fact that earlier ADM network software did not need such reports, as there were no relationships to analyze. Perhaps it did not occur to the software developers to add such analyses when they switched to creating PDM network software. Later software developers have just perpetuated this trend (or lack thereof). For whatever reasons, the PDM software that currently exists fails to calculate or provide access to the assessment of relationship attributes.

Statusing the Remaining Lag

Why would relationship performance be of interest to the scheduler? The first obvious need is evident when updating the schedule and a relationship lag is on-going; for example, as of the current data date, the relationship is five days into a planned ten day lag. While the scheduler assessing the current project status reviews the remaining duration of all on-going activities, who reviews the remaining relationship lag?

The most obvious answer is, 'no one reviews the status of the ongoing lag' as the status of remaining lag is not typically provided by the CPM software. Schedulers are often known to say that they do not depend upon the software to perform their assessment of project status. This boast does not typically extend to evaluation the status of relationships, as even determining what workday calendar the relationship is using can vex most.

The Anatomy of a Relationship

A positive variance in lag causing project delay indicates that there was a problem in completing the relationship. What would cause an inability to start the successor task immediately when allowed for by relationship logic? There is more to constraining activity start than just logical relationships.

Before an activity can start, there are two constraining forces: logical predecessors, and administrative requirements. Administrative requirements include such things as: [4]

- Access to the work area,
- Availability of required utilities,

- Required materials and tools being present,
- Supervision,
- Useable plans, and
- Enough qualified workers present.

There may even be enough qualified workers present for one task but not enough to work on all of the tasks that could be performed at the same time. This is a very common occurrence and it is often uneconomical or even impossible to hire more. In this instance the contractor typically works on one available task and delays the start of the others to stage the workers to work on one parallel task at a time. As long as the delayed activities have sufficient float to allow for the activities to be delayed without affecting project completion, then a more optimal arrangement has been achieved.

Properties of a Relationship

The question of why one might need to measure as-built relationship lags is answered by the adage, "you can't manage what you can't measure".[6,7] It is obvious that the scheduler cannot manage schedules containing lags if they are unable to measure their durations and assess the success rate of the plan.

Relationships behave similarly to activities in a PDM schedule. Both have duration. Even relationships with zero lag are similar to activities with zero duration (i.e. milestones). The only real difference between the two is that CPM theory assumes that relationships do not consume any resource other than time. This means that the scheduler cannot assign resources to relationships. Other than this, any limitations to relationships are merely software-driven.

It is not widely known that relationships have float. With activities having more than one successor relationship, this relationship float may be different than the activity's total float or free float.[8] As a point of fact, Oracle/Primavera P6 software currently reports the relationship float on the relationship tab.

Activities often experience non-linear, uneven progress.[9] Most CPM algorithms are based on the assumption that relationships experience even, planned progress. They do not provide a method for assessing the current state of a relationship's lag. This is a failure of current CPM software, not an inherent deficiency of relationships.

Relationship Float Consumption

In order to not delay the project, CPM theory does not require a successor activity to start immediately as soon as its early start date is reached, only to start by the late start date. Activities that start later than their early start date but prior to the late start date use up part of the available total float of the relationship and eventually that of the successor activity.

Activities that had project float can become project critical if the start of the activity is delayed long enough. It might be said that the delay in executing the predecessor relationship is the cause of the change of the critical path. Tracking relationship as-built status to activity float can identify those activities that contributed or even caused the path to turn critical. A benchmark as-built relationship report [10] can demonstrate this analysis. Figure 1 below tracks planned versus as-built relationship duration and compares the variance in terms of the predecessor and successor's activity float.

							----------Lag Duration----------				Lost	
Pred	C	Float	Succ	C	Float	Type	Planned	Actual	Remaing	Variance	Float	
A1000	Y	-76	A9050	N	-19	FS	0	0	0	0	-57	
A1000	Y	-76	EW003	N	140	FS	0	163	0	163	-216	
A1000	Y	-76	A9630	N	144	FS	0	196	0	196	-220	
A1000	Y	-76	A8250	N	113	FS	0	0	0	0	-189	
A1000	Y	-76	A1200	N	83	FS	0	0	0	0	-159	
A1000	Y	-76	A1380	Y	-54	FS	0	0	0	0	-22	
A1000	Y	-76	A1050	N	73	FS	0	0	0	0	-149	
A1000	Y	-76	A2460	N	82	FS	0	126	0	126	-158	
A1000	Y	-76	A7550	N	117	FS	0	84	0	84	-193	
A1050	N	73	A1070	N	73	FS	0	0	0	0	0	
A1070	N	73	A1080	N	73	FS	0	-1	0	-1	0	
A1850	Y	-54	A9830	Y	-56	FS	0	19.6	0	19.6	2	*
A10930	N	2	A10950	N		FS	0	13	0	13		
… … …												

Figure 1, Benchmark As-Built Relationship Report

The column headers are more completely defined as the following:

- Pred Predecessor activity ID
- C Was the predecessor activity on the longest path?
- Float Last total float reading before completion of predecessor
- Succ Successor activity
- C Was the successor activity on the critical path?
- Float Last total float reading before completion of successor

- Type Relationship type (FS/FF/SS/SF)
- Planned Lag Duration Original lag value
- Actual Lag Duration Actual lag
- Remaing Lag Duration Any remaining duration of in-progress lag
- Variance Lag Duration Actual + Remaining - Planned Lag duration
- Lost Float Successor – Predecessor total float
- * Critical predecessor and successor with positive lost float

The line in Figure 1 marked by an asterisk (*)displays a critical relationship that lost critical float during its execution. It might be said that relationship A1850/A9830-FS/0 delayed the project by 2 days.

One of the difficulties of comparing lag variance against activity total float consumption is that completed activities do not display a useable total float value. To overcome this problem, a time-wise backward search through the saved baseline schedules must be made to discover the last schedule displaying useable total float values for that activity. These are the values used in the report above. They are the most appropriate values to use as they were reported just prior or during the activity's execution and the closest documented as-built float value.

Considering the factor of total float, a lag may mean, "at least x amount of time". This gives rise to the question of how often does the relationship finish early? The study detailed in Appendix A, Lag Variance Statistics suggests an answer. Of the 147,048 actual lags observed, 19% of them finished early with a standard deviation of 22%. This indicates that early starts across the entire spectrum of relationship types and lags are not very common.

Measuring Relationship Progress

Relationship actual performance can be benchmarked just like other schedule factors. The obvious measurement of the average difference between planned and actual relationship duration can be made. The standard deviation of the variance of that measurement gives the analyst a sense of how varied the readings were.

If a criterion was established to define which variances were on-time, then three categories (early, on-time, and late) can be established. Each category can have their statistics tallied as a percentage of the whole. The sample statistics for one schedule displayed in Figure 2 below are based upon on-time being defined as any variance less than one day (-0.999 to 0.999 days), but this differentiation could be set to any number. [10]

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============================
RELATIONSHIP ACTUAL DURATION
SCHEDULE QUALITY STATISTICS
____________________________


    All Relationships

Total relationships analyzed             : 1484
Total relationships with actual progress : 425
Median of the lag variance               : 10
Standard Deviation of lag variance       : 32.57
Number of early relationships            : 22
    Percent of early relationships       : 5.18%
Number of on-time relationships          : 236
    Percent of on-time relationships     : 55.53%
Number of late relationships             : 167
    Percent of late relationships        : 39.29%


    Just Critical Relationships

Total critical relationships             : 53
Median of critical lag variance          : 1
Standard Deviation critical lag variance : 7.39
Number of early critical relationships   : 6
    Percent of early critical rels       : 11.32%
Number of on-time critical relationships : 29
```

Figure 2, Relationship Actual Duration Statistics

Critical Relationships

Another important consideration when measuring lag variance is whether or not the relationship is critical. A critical relationship is characterized as one where both the predecessor and successor activities are considered critical. In this example, a progressed relationship is considered critical if it has both predecessor and successor activities on the longest path. Of course, the critical setting is determined by the software program and might either be based on critical float or longest path, if supported.

Reporting on Non-Zero Lags

Given a particular planned lag, what is the average result of being on-time? When a non-zero lag is assigned, it can be assumed that the duration was the result of some sort of active analysis of the intended time duration. In this case, how well does the average project do in meeting those estimates?

Each value of planned lag could be individually analyzed to obtain the performance of relationships with zero lags as opposed to those with original lags set to, say 10. One would expect a larger variation of planned versus actual for lags set to zero when compared to those with nonzero values. If a planner decided to set the lag to 10, then it would seem likely that a particular, measured delay was intended.

Figure 3 below displays the statistics for each planned lag in a particular schedule. Only the lags that were actually found in the schedule are mentioned here. [10]

Planned Lag-Val	Number of-Lags	Average Actual	Number On-Time	Percent On-Time	Number Early	Percent Early	Number Late	Percent Late
0	725	31	115	15.86	149	20.55	461	63.59
1	32	21	0	0	1	3.12	31	96.88
2	3	9	0	0	0	0	3	100
5	8	3	2	25	4	50	2	25
10	1	2	0	0	1	100	0	0
65	1	65	1	100	0	0	0	0

Figure 3, Individual Planned Lag Statistics

The column headers are more completely defined as the following:

- Planned Lag-Val — The planned (original) relationship lag value
- Number of-Lags — The number of relationships who had that planned lag value
- Average Actual — Average actual relationship length for that planned lag value
- Number On-Time — The number of relationships with that planned lag value which finished on-time
- Percent On-Time — The percentage of on-time relationships with that lag value
- Number Early — The number of relationships with a negative variance

- Percent Early — The percentage of on-time relationships with a negative variance
- Number Late — The number of relationships with a positive variance
- Percent Late — The percentage of on-time relationships with a positive variance

The same analysis can be further broken-down through grouping and summarizing by activity codes such as Responsibility. Since most software do not provide for relationship code assignments, we will need to use either the predecessor's activity code or the successor's. An actual example of this using the successor's activity codes is shown in Figure 4 below. [10]

Act Code	Planned Lag-Val	Number of-Lags	Average Actual	Number On-Time	Percent On-Time	Number Early	Percent Early	Number Late	Percent Late
Client	0	100	1	25	25	3	3	72	72
Contractor	0	325	34	66	20.31	48	14.77	211	64.92
Designer	0	217	20	64	29.49	8	3.69	145	66.82
Supplier	0	61	7	11	18.03	3	4.92	47	77.05
Contractor	1	1	4	0	0	0	0	1	100
Contractor	2	1	2	1	100	0	0	0	0
Designer	4	4	22	0	0	1	25	3	75
Contractor	4	3	3	0	0	1	33.33	2	66.67
Contractor	5	3	8	0	0	0	0	3	100
Contractor	8	5	52	0	0	1	20	4	80
Supplier	8	1	32	0	0	0	0	1	100
Contractor	11	1	88	0	0	0	0	1	100
Contractor	12	2	52	0	0	0	0	2	100
Supplier	15	1	28	0	0	0	0	1	100
Supplier	16	1	28	0	0	0	0	1	100
Contractor	22	1	20	0	0	1	100	0	0
Contractor	24	1	152	0	0	0	0	1	100

Figure 4, Individual Planned Lag Statistics by Responsibility

Most of the planned lags were set at zero, but this particular value can be further broken-out by client, contractor, designer, and supplier (if the activity coding structure supports this). One can see that in this instance, the client had a very good record of 1 day over while the contractor was averaging 34 days late.

Charting the statistics sometimes leads to new insights. The charting process for on-time lags does not always yield good results as the first category, zero planned lag is usually so dominant in size in relation to the other figures. The example below in Figure 5 shows how the Responsibility activity code can be used to illustrate the concrete contractor's success in meeting the plan.

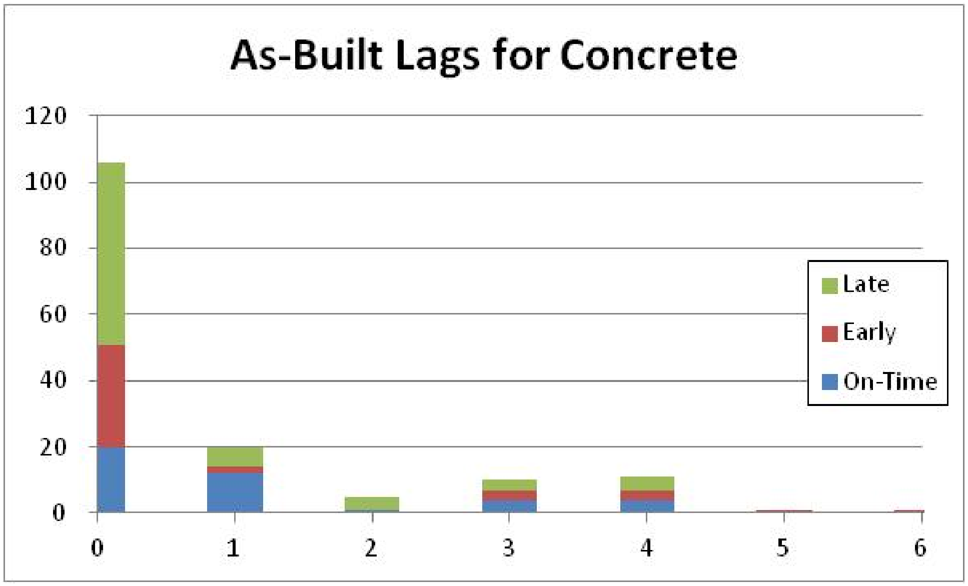

Figure 5, Charting Lag Results for a Specialty Contractor

Benchmarking Relationship Progress

Individual schedule evaluation results can be compiled to create a bigger picture of the success of lag execution across the industry. In the study documented in Appendix A, 46 different, independent as-built schedules were evaluated for the variance between planned and actual relationship lag. The average variance between planned and actual lags was 26 days late with a standard deviation of 22 days. Schedules whose average variance between planned and actual relationship lags fell beyond one standard deviation of our study would have a variance greater than 48 (26 + 22) days. Seven schedules in our study failed in this regard.

When the definition of finishing the relationship on-time is a variance less than one (-0.999 to 0.999 days), analysis revealed that

- 19% of the relationships finished early,
- 20% finished on-time, and
- 61% of them finished late.

One might question the factor that total float plays in the on-time completion of a relationship. It would seem reasonable to suppose that in conditions of high total float, the construction foreman would be less pressured to complete the relationships judiciously. To test out this theory, critical lags were isolated and evaluated (see Appendix B). This study defined a critical lag as any relationship between two critical activities.

The average variance between planned and actual critical lags was 8 days late with a standard deviation of 20 days. In other words, our assumption was correct in that critical lags were three times better managed that the total population.

When the definition of finishing a critical relationship on-time is a variance less than one (-0.999 to 0.999 days), analysis revealed that

- 20% of the relationships finished early,
- 22% finished on-time, and
- 58% of them finished late.

Stated again, the critical lag variance closely resembled the variance shown over the entire population of relationships when using a standard of 1 day but averaged a much better record overall.

Non-Zero Lag Accuracy

If a non-zero planned lag value is specified, how accurate is the result? The planner must have had some idea about the lag duration or they would have just left the lag at zero and let any delay in starting the successor activity fall within the total float envelope. This line of reasoning leads to the supposition that non-zero planned lags should be more accurate than ones with the classical finish-to-start with zero lag. Are negative lags more accurately planned and managed then positive ones? Appendix C, Lag Variance Statistics suggests an answer.

Where planned negative lags were documented, the average relationship actually finished 4 days later than the plan with a standard deviation of 18 days. Planned negative lags on average really did finish later than estimated. Zero lags averaged 26 days late with a standard deviation of 23 days. Where planned positive lags were documented, the average relationship finished 17 days later than the plan with a standard deviation of 18 days. This indicates that on the average, negative lags are managed much better than positive ones, with in turn ad managed better than zero lags.

Scheduler's Short-Cut

A different consideration is how often a finish-to-start relationship with zero lag is used when a small negative lag was actually envisioned. This condition is sometime called, scheduler's short-cut. [11,12] The scenario behind it involves the planner making a simplification of a non-linear process to fit the classic finish-to-start with zero lag nomenclature.

This abstraction of a relationship is sometimes done to meet the specifications as developed by the project owner. Sometimes this simplification is used to reduce schedule complexity. The technical requirement behind this is that succeeding work can begin prior to the planned finish of an activity as long as it does not interfere or overtake the preceding work.

A study of 46 different, independent schedules was made to investigate the frequency of the scheduler's short-cut in actual construction projects. All completed finish-to-start relationships with zero planned lag were evaluated to find the frequency of those that actually started before the predecessor by less than 3 days (i.e. with an actual lag greater than -3.0 days and less than 0.0). Appendix D, Other Lag Statistics summarizes the results of that study.

A total of 97.83% of the schedules displayed evidence of the scheduler's short-cut.   Only one schedule showed no signs of this phenomenon. Two other schedules indicated at approximately 30% of successors in finish-to-start relationships with planned zero-lag actually began 1 or 2 days early. The average occurrence was 8% of the finish-to-start zero-lag relationships starting less than 3 days early with a standard deviation of 7%.

Other facts about the actual use of relationships are also presented in Appendix D. Lags greater than zero were used in 87% of the schedules observed. Negative planned lags were used in 24% of the observed schedule population. The largest lag used in the schedules averaged 86 days.

The Future of Relationship Tracking

One of the authors of a major textbook on construction CPM [5] has long lobbied for improvements in the features for relationships in the scheduling software market. He has created a list of features that when incorporated in any particular scheduling software will earn it a RDCPM™ certification. The required features include:

- The ability to identify where several relationships converge on the same successor activity and create points of merge bias as reportable 'mini-milestones'.
- User-definable codes and textual narratives for each relationship in the schedule.
- The ability to select relationships by combinations of codes from the predecessor and successor activities.
- An expansion of the types of relationships to better describe the conditions behind the relationship.
- Treatment of lag durations like activity durations and allowance of individual calendar and other duration types to be individually assigned.
- Allowance for automatic duration adjustments based on actual productivity.
- Allowance for complex logic based upon rule sets.
- Improved handling of out-of-sequence progress.
- Expanded float measurement types to include multi-calendar float and path free float.

Some manufactures of CPM software have already earned various degrees of RDCPM certification. As an example, Primavera PertMaster™ has received a partial RDCPM certification.

In addition to these enhancements, the following relationship features are also needed:

- The display of remaining lag duration.
- The display of actual lag duration.
- The display of lag as-planned/as-built variance.
- The ability to sort relationship reports based on planned lag.

Conclusion

When software vendors switched from ADM to PDM networks, they apparently forgot to expand their reporting range to cover the assessment of relationship performance. This

information is important for controlling a project. For example, without relationship performance assessment, remaining active lag is unknowable.
Managing and controlling timely completion of relationships requires the scheduler to understand the various components that all contribute to the start of the successor activity. Relationships can have many of the properties that a CPM activity has. The absence of these properties in modern-day schedules is a matter of software vendor offerings and not that of logic or need.

The consumption of relationship float on a project over time can be documented and analyzed. This can lead to identification of failed project management oversight and even identifying non-network caused changes to the critical path. This type of study requires the referencing of previously statused schedules from earlier data dates to identify the activity's as-built critical float.

Relationship actual performance can be benchmarked to identify planned versus actual lag duration variance. Criteria can be defined to generalize and catalog the various properties of a relationship relative to the observed variance. In consideration of relevant figures, the lag variances can be limited to just those of critical relationships or of a particular responsible party working on the project.

General benchmarking results of on-time completion of relationships indicate that approximately 20% finish early, 20% finish on-time, and 60% finish late. This general profile usually holds true for the entire population of relationships as well as when just considering critical relationships.

On the average, successors in relationships with planned negative lags ended up actually occurring fairly close to planned, while successors in relationships with planned positive lags occurred significantly later than planned. In other words, relationships with non-zero lags tend to be managed better than relationships with zero lags.

The scheduling phenomenon called scheduler's short-cut is a real and documented condition. Approximately 8% of finish-to-start relationships with zero lag are actually started early but less than three days earlier than planned.

The future of CPM includes enhanced recording and reporting of relationship properties and statistics. Several features including the reporting of remaining and actual lag durations are desperately needed right now. Others may wait for competitive enhancements in the marketplace.

References

1. H. L. Stephenson, Ed., Total Cost Management Framework: An Integrated Approach to Portfolio, Program and Project Management, 2nd ed., Section 10.1 Morgantown, WV: AACE International, Latest revision
2. Construction Scheduling. Schedule Performance Measurement, Part 5. (For Owners), Paul Epperson CCM, PMP, PSP, PMI-SP, Construction and Schedule Management Services, LLC, https://conschmanservices.com/scheduling-tips/tag/schedule-revision/
3. AACE International, Recommended Practice No. 10S-90, COST ENGINEERING TERMINOLOGY, Morgantown, WV: AACE International, Latest revision
4. CPM in Construction Management, Fifth Edition, O'Brien and Plotnick, McGraw-Hill, 1999
5. CPM in Construction Management, Sixth Edition, O'Brien and Plotnick, McGraw-Hill, 2005, Page 21
6. RISK-2929, Improving Risk Management Effectiveness by Testing Risk Relevance, James E. Arrow, DRMP
7. Who said, "You can't manage what you can't measure"?, John Hardway, 2018
8. https://www.quora.com/Who-said-You-cant-manage-what-you-cant-measure
   https://en.wikipedia.org/wiki/Peter_Drucker
   https://en.wikipedia.org/wiki/W._Edwards_Deming
9. PS.11, Computing the Near-Longest Path, Ron Winter, PSP, FAACE, AACE International Transactions 2003
10. PS-2127, CPM Really Gets Interesting When You Consider Activity Status, Ron Winter, PSP, FAACE, AACE International Transactions 2016
11. Schedule Analyzer Enterprise Forensic software, Benchmark Module. Version 2.09, 2019
12. CRD-1815, Forensic Schedule Analysis and Discretionary Logic, John Livengood Esq., CCP, CFCC, PSP, AACE International Annual Meeting, 2015
13. PS-3006, Reporting on Out-of-Sequence Progress, Ron Winter, PSP, FAACE, AACE Annual Meeting, 2018

Appendix A

Lag Variance Statistics (Average per schedule)

On-time is less than 1 day variance

				Early		On-Time		Late	
Schedule Name	Started Rels	Ave Lag Variance	St. Dev Variance	Total	Percent	Total	Percent	Total	Percent
EKR2	41	-2	12	24	59%	12	29%	5	12%
PL03	77	-1	33	23	30%	19	25%	35	45%
HQNE	146	0	13	54	37%	29	20%	63	43%
PARK	152	2	8	15	10%	51	34%	86	57%
TR11	128	3	27	35	27%	29	23%	64	50%
SP10	78	5	13	6	8%	17	22%	55	71%
0009	216	8	16	15	7%	46	21%	155	72%
SA11	954	8	88	279	29%	85	9%	590	62%
UP12	638	9	42	71	11%	187	29%	380	60%
6800	425	10	33	22	5%	236	56%	167	39%
COUR	6021	10	45	998	17%	967	16%	4056	67%
VOGL	96	11	30	9	9%	41	43%	46	48%
CPWT	1204	12	149	422	35%	202	17%	580	48%
POLB	269	12	41	64	24%	29	11%	176	65%
OMVP	643	13	89	195	30%	32	5%	416	65%
0755	1940	14	63	697	36%	113	6%	1130	58%
CHOP	10808	14	68	2998	28%	1841	17%	5969	55%
MULE	7244	14	36	740	10%	2092	29%	4412	61%
HQNG	5311	16	37	394	7%	1524	29%	3393	64%
WTPR	731	17	88	185	25%	87	12%	459	63%
7031	676	18	41	69	10%	144	21%	463	68%
JG09	526	19	38	95	38%	42	8%	389	74%
C001	92	20	26	11	12%	17	18%	64	70%
PS43	7644	21	91	2638	35%	753	10%	4253	56%
SHTE	1161	21	41	145	12%	222	19%	794	68%
2W52	4672	23	107	1468	31%	561	12%	2643	57%
HYD4	728	23	54	66	9%	167	23%	495	68%
0575	203	28	72	16	8%	82	40%	105	52%
1134	5101	30	55	527	10%	709	14%	3865	76%
A031	770	31	97	155	20%	118	15%	497	65%
CU38	15234	31	61	2688	18%	1883	12%	10663	70%
HWY2	5915	32	73	840	14%	1318	22%	3757	64%
1501	7513	35	98	1020	14%	1748	23%	4745	63%
HQNS	945	35	63	95	10%	166	18%	684	72%
3332	972	37	88	185	19%	162	17%	625	65%

2827	6133	42	128	1149	19%	1043	17%	3941	64%
X101	2943	44	94	390	13%	380	13%	2173	74%
VERY	21270	45	97	2149	10%	6087	29%	13034	61%
S053	5066	47	83	192	4%	2231	44%	2643	52%
RT58	385	49	106	47	12%	46	12%	292	76%
B114	2147	52	192	334	16%	522	24%	1291	60%
X042	1641	52	161	208	13%	321	20%	1112	68%
BT29	1201	58	160	248	21%	223	19%	730	61%
0813	1185	61	213	376	32%	131	11%	678	57%
0354	14281	93	273	1339	9%	3610	25%	9332	65%
PLPB	1522	95	202	314	21%	70	5%	1138	75%
Mean		26			19%		20%		61%
St. Dev.		22			12%		11%		12%
Totals: 46	147048			24010		30395		92643	

Appendix B

Critical Lags

Note: Schedules without a viable longest path were excluded from this check.

On-time is less that 1 day variance.

Schedule Name	Started Rels	Ave Lag Variance	St. Dev Variance	Early		On-Time		Late		Crit Lag Delays
				Total	Percent	Total	Percent	Total	Percent	
0009	4	1	1	0	0%	1	25%	3	75%	0
0813	20	42	80	1	5%	5	25%	14	70%	2
1501	3	2	1	0	0%	1	33%	2	67%	0
2827	1	-44	0	1	100%	0	0%	0	0%	0
3332	96	21	79	14	15%	30	31%	52	54%	5
7031	5	2	5	0	0%	2	40%	3	60%	2
0755	29	-8	33	11	38%	3	10%	15	52%	4
2W52	50	-13	56	27	54%	6	12%	17	34%	0
3332	31	21	37	4	13%	3	10%	24	77%	7
6800	53	1	7	6	11%	29	55%	18	34%	3
B114	2114	47	190	333	16%	521	25%	1260	60%	0
BT29	30	79	246	5	17%	9	30%	16	53%	3
COUR	4	1	0	0	0%	1	25%	3	75%	0
CPWT	114	20	133	30	26%	21	18%	63	55%	0
CU38	19	16	20	3	16%	1	11%	14	74%	4
EKR2	11	-4	2	10	91%	0	0%	1	9%	0
HQNE	3	7	9	1	33%	0	0%	2	67%	0
HQNS	1	21	0	0	0%	0	0%	1	100%	0
HWY2	9	1	3	2	22%	4	44%	3	33%	0
HYD4	52	21	43	10	19%	4	8%	38	73%	6
JG09	1	-1	0	0	0%	0	0%	1	100%	0
MULE	101	2	8	18	18%	25	25%	58	57%	10
OMVP	9	6	20	2	22%	0	0%	7	78%	0
PARK	8	0	1	1	13%	4	50%	3	38%	0
PLPB	6	6	8	1	17%	2	33%	5	50%	0
PS43	11	-6	27	3	27%	1	9%	7	64%	0
RT58	5	14	12	0	0%	1	20%	4	80%	0
S053	33	5	19	2	6%	20	61%	11	33%	2
SA11	16	14	13	0	0%	0	0%	16	100%	3
SP10	15	2	18	1	7%	5	33%	9	60%	0
TR11	8	2	30	2	25%	2	25%	4	50%	0

UP12	9	1	1	1	11%	3	33%	5	56%	0
VOGL	15	1	8	2	13%	9	60%	4	27%	0
X101	61	4	53	19	31%	8	13%	34	56%	2
Mean		8			20%		22%		58%	2
St. Dev.		20			23%		18%		23%	2.5
Total: 34	2947			510		721		1717		

Appendix C

Planned Lag Variance Statistics

		Negative lags		Zero Lags		Positive Lags	
Schedule Name	Total Act Rels	Total	Ave Lag Variance	Total	Ave Lag Variance	Total	Ave Lag Variance
0009	216	0		204	8	12	-1
0354	14281	0		14093	93	188	39
0575	203	0		203	28	0	
0755	1940	7	-8.29	1926	14	7	26
1134	5101	0		4834	31	267	13
1501	7513	0		6827	36	686	15
2827	6133	8	34.5	6025	42	100	9
2W52	4672	0		3888	14	784	54
3332	972	0		893	37	79	33
6800	425	0		425	10	0	
7031	676	0		659	18	17	33
A031	770	0		725	31	45	14
B114	2147	119	-24.41	1925	55	103	37
BT29	1201	0		1173	59	28	6
C001	92	0		92	20	0	
CHOP	10808	16	6.88	9223	12	1569	20
COUR	6021	5	-14.2	5573	10	443	3
CPWT	1204	0		1204	12	0	
CU38	15234	0		14406	32	828	12
EKR2	41	0		13	-2	28	-10
HQNE	146	0		142	0	4	-4
HQNG	5311	9	9	5196	15	106	32
HQNS	945	5	1	873	37	67	1
HWY2	5915	0		5665	32	250	33
HYD4	728	0		703	23	25	25
JG09	526	0		515	19	11	0
MULE	7244	0		6419	16	825	2
OMVP	643	0		638	13	5	18
PARK	152	0		139	3	22	-2
PL03	77	0		65	-4	12	12
PLPB	1522	0		1421	101	101	1
POLB	269	0		269	12	0	
PS43	7644	3	34	6642	19	999	22

RT58	385	0		344	49	41	44
S053	5066	0		4905	46	161	75
SA11	954	1	5	943	8	10	-2
SHTE	1161	0		1158	21	3	25
SP10	78	0		78	5	0	
TR11	128	0		111	2	17	-3
UP12	638	1	-2	607	9	30	13
VERY	21270	0		20439	46	831	25
VOGL	96	1	6	91	11	4	1
WTPR	731	0		694	17	37	0
X042	1641	0		1622	53	19	11
X101	2943	0		2868	44	75	28
Mean			4		26		17
St. Dev.			18		23		18
Totals: 46	145863	175		136858		8839	

Appendix D

Other Lag Statistics

Schedule Name	Total Act Rels	Scheduler's Shortcut Total	Scheduler's Shortcut Percent	Lags Used?	Negative Lags?	Largest Lag
0009	216	9	4%	Yes	No	3
0354	14281	3129	22%	Yes	No	43
0575	203	18	9%	No	No	
0755	1940	118	6%	Yes	Yes	60
0813	1185	81	7%	Yes	No	20
1134	5101	246	5%	Yes	No	140
1501	7513	565	8%	Yes	No	60
2827	6133	191	3%	Yes	Yes	240
2W52	4672	47	1%	Yes	No	95
3332	972	36	4%	Yes	No	2
6800	425	34	8%	No	No	
7031	676	100	15%	Yes	No	190
A031	770	17	2%	Yes	No	65
B114	2147	27	1%	Yes	Yes	492
BT29	1201	124	10%	Yes	No	97
C001	92	0	0%	No	No	
CHOP	10808	534	5%	Yes	Yes	85
COUR	6021	155	3%	Yes	Yes	100
CPWT	1204	34	3%	No	No	
CU38	15234	309	2%	Yes	No	220
EKR2	41	1	2%	Yes	No	60
HQNE	146	28	19%	Yes	No	6
HQNG	5311	718	14%	Yes	Yes	28
HQNS	945	25	3%	Yes	Yes	48
HWY2	5915	503	9%	Yes	No	180
HYD4	728	18	2%	Yes	No	24
JG09	526	50	10%	Yes	No	8
MULE	7244	237	3%	Yes	No	120
OMVP	643	125	19%	Yes	No	20
PARK	152	1	1%	Yes	No	28
PL03	77	11	14%	Yes	No	18

PLPB	1522	33	2%	Yes	No	210
POLB	269	89	33%	No	No	
PS43	7644	208	3%	Yes	Yes	109
RT58	385	50	13%	Yes	No	55
S053	5066	290	6%	Yes	No	30
SA11	954	82	9%	Yes	Yes	7
SHTE	1161	184	16%	Yes	No	18
SP10	78	9	12%	No	No	
TR11	128	12	9%	Yes	No	77
UP12	638	183	29%	Yes	Yes	55
VERY	21270	1043	5%	Yes	No	156
VOGL	96	2	2%	Yes	Yes	30
WTPR	731	14	2%	Yes	No	122
X042	1641	28	2%	Yes	No	99
X101	2943	55	2%	Yes	No	18
Mean			8%			86
St. Dev.			7%			92
Totals: 46	147048	9773		87%	24%	