Simulated Schedule Delay Mitigation via Float Allocation

by

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Overview

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  - Scheduling assumptions, criticality paradox
  - Float ownership, fair allocation
- Research Methodology
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- Simulation Calculations
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  - Results and interpretation
- Conclusions and Recommendations

Introduction

- Delays inundate construction (Gündüz *et al.* 2013)
- Act not just locally, but may have ripple effects
- Caused by risk factor(s) that materialize (González *et al.* 2013) and have been amply studied already
- Effects of late completion: Lost bonus, liquidated damages, claims, court cases, damaged reputation

  → Should cure cause (preventive), not symptoms:

  What inherent defense schedule has against delay?

Scheduling Assumptions

- Acyclic networks (Chen *et al.* 2001)
  - Critical path method (Kelley and Walker 1959) sequentially adds durations: $max\ \{F_{pred}\} = S_{succ}$
  - Best case if all activities start as soon as possible
  - Compare with worst case: *How much can it be delayed until…*

    Impact any succ.: $FF_{pred} = min\{ES_{succ}\} - EF_{pred}$)

    Impact project: TF = LF-EF = LS-ES (used here)
- Float is defined by assumed delay / opposite of criticality (de la Garza *et al.* 2007)
- Focus should be on delay avoidance, not claims

Hidden Assumptions

- Links: For technical reasons, but also administrative reasons, or even to create or reduce float (Zack 1992)

  → Assume links as fixed

- Durations: Determined from quantity take-off and resource unit productivity
  - Distributions for probabilistic durations possible (Khamooshi & Cioffi 2013)
  - In practice, ‘raw’ plus contingency (added float)

  → Assume durations as unmodified

- Contingency “used in project planning to cover activities delays, oversights, and unknowns and as a cushion for possible time-estimating errors” (Barraza 2011, p. 259)

Criticality Paradox

- Definition of criticality as 'inability to absorb delays'
  - Based on assumption that activities are unequal
  - But schedulers create criticality and float as artifacts of chosen links and durations (Zack 1992)
  - Not inherent to nature of activity or its unique risk

- Artificial split: "By definition, noncritical subcontractors have float, but… critical ones have none, even though they need it most" (Thompson & Lucko 2012, p. 488)
  - Counterintuitive: One activity type on verge of failure

- Goal: *Create schedule that minimizes overall risk level (or probability of local delays affecting any successor) of all activities by allocating each float that it*

Float Ownership

- Schedulers have to use "subjective management of the project time contingency" (Barraza 2011, p. 260)
  - Empirical approach only
  - Quantify and formalize float need for realism
- Float mitigates delays
  - Becomes valuable commodity (de la Garza *et al.* 1991)
- Contentious unresolved issue: *Who owns float?*
  - First-come, first-served? (Pasiphol 1994)?
  - Owner or contractor? (Al-Gahtani 2006)?
  - Split somehow (Prateapusanond 2003)?

→ Should link "ownership with the party who carries the risk" (Al-Gahtani & Mohan 2007 p. 33)

Fair Allocation

- *Who should own float, and how much?*
  - Activities on critical path in as-planned schedule
  - Allocated from pool at project end, between sum of raw durations and contract deadline
  - Inverse to critical chain project management (CCPM)
- But: CCPM aggregates, not allocates
  - Radically removes all buffers, simplistically reduces 50% "the likely duration" (Zhao *et al.* 2010, p. 1056)
  - Creates project buffer (Rand 2000), changes dates
  - Then reinserts 'feeding buffers' on *non*-critical paths
  - Focus on duration, not risk (Herroelen & Leus 2001)
- Fair quantitative approach is required *a priori*

Methodology

- Analogy-adapting to create mathematical approach
- Inspired by social science (Thompson & Lucko 2011)
  - Compare float allocations – fair and equitable?
  - Buffer simulation not *a priori* (Park & Peña-Mora 2004)
- Initial assumptions
  - Raw durations w/o contingency, risk ~ duration
  - Weighted combination of time, cost, other factors will be examined under future research
- Definition: *CF = contract finish – calculated finish*
  - Critical path from baseline as-planned schedule

Square-Root Analogy

- Decision-making (Arrow 1964): Voting versus markets
  - Rules and hierarchies to reach a consensus
  - Social choice problems: Fair division, voting models
  - {System, voters, decision} ↔ {project, subs, delay}
- Fairness challenge if participants have unequal 'size'
- Two related models:
  - Penrose (1946) square root law (inspired by UN)
  - Banzhaf (1965) power index

  Both explore how to fairly balance 'small' vs. 'large' participants so that they neither never nor always dominate a decision (in majority or as tiebreaker)

Inspiration

- Penrose (1946, p. 53) inspires new float allocation:

  [P]ower of the individual vote[*r*] *can be measured by the amount by which his chance of being on the winning side exceeds one half. (…) [F]ormula for the probability of equal division of random votes, where* n *is an even number, approaches* $\sqrt{2/n\pi}$ *when is large. It follows that the power of the individual vote[r] is inversely proportional to the square root of the number of people in the committee.*

- Distinguished weight (factor) from power (changing a decision) → All participants should have equal power

- Population n of EU countries, unfair extremes:
  - *'One vote per country'* ($\sim n^0$)
  - *'One vote per person'* ($\sim n^1$)

Methodology

- Transfer conceptual analogy to network schedules:
  - Vote Y/N ↔ Use float (due to delay) or not
  - Voters ↔ Subcontractors
  - Election ↔ Project
  - {System, voters, decision} ↔ {project, subs, delay}
- Hypothesis

  It is hypothesized that allocating float to the activities on the critical path based on the square root of the measure of float need leads to less need for project float than an allocation based on order zero or one.

Simulation

- Modular computer implementation:
  - Input text file: Activities, links, duration distributions
  - Output text file: Post-processed for analysis
  - Each run samples distributions for unique project
- Monte Carlo method (Chantaravarapan *et al.* 2004)
- Criticality index (CI, Tang *et al.* 2013, p. 3238) "is… the probability of an activity becoming critical", BUT:
  - CI based on (difficult) distr. of full duration, not raw
  - CI exists within calculated project duration, no CF
  - CI assumes critical path may vary (more complex)
  - Float allocation sim. will vary and chart dur. and CF

Simulation

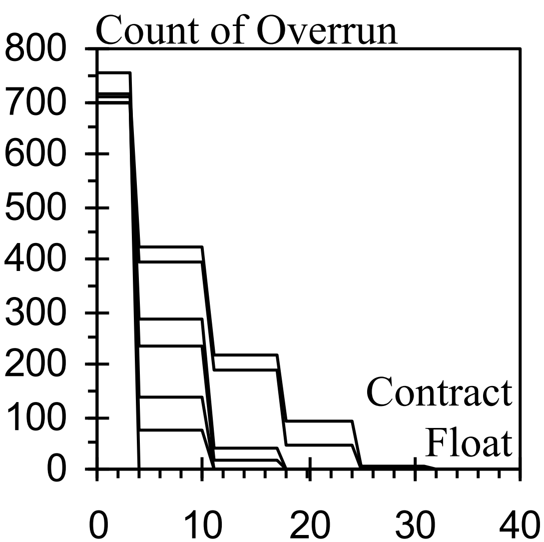
- Assume asymmetric triangular distr. 90%/100%/125%
- Realistic because activities take longer more often
- Future research will use e.g. beta (Fente *et al.* 2000)
  - Forward / backward pass and float of baseline schedule with fixed durations → critical path
  - Replace with distr. for 1000 repetitions, *CF*={1-40}
  - Distributed float (*DF*) is *a priori* allocated part of *CF*
  - Post-processing (1 run, not 40):
    ActualD – (PlannedD + DF) = Float overrun
- Rounding is future challenge: Limited valuable integer *CF* becomes integer *DF* for critical subcontractors

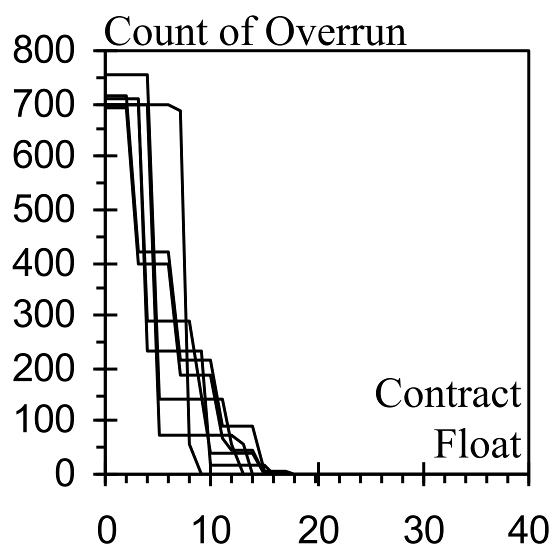
Case Example Input and Allocation

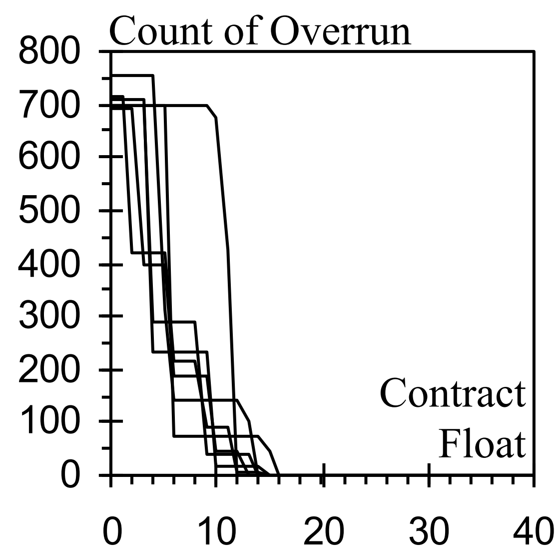
Traditional CPM Calculations									Duration$^{0.0}$				Duration$^{0.5}$				Duration$^{1.0}$			
Act.	Dur.	Succ.	*ES*	*LS*	*EF*	*LF*	*TF*	*FF*	*L*	*R*	*m*	*s*	*L*	*R*	*m*	*s*	*L*	*R*	*m*	*s*
Mob.	7	A, B, E	0	0	7	7	0	0	3	11	4.80	3.85	4	13	5.87	3.52	4	14	6.34	3.82
A	19	D, I, J	7	13	26	32	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B	10	C	7	7	17	17	0	0	3	18	5.98	4.53	3	16	5.62	3.65	3	15	5.60	3.79
C	6	D, F, J	17	17	23	23	0	0	3	11	4.24	3.05	4	14	5.43	3.32	5	16	6.52	3.64
D	18	L	26	33	44	51	7	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E	15	F, G	7	8	22	23	1	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F	17	H, I, K	23	23	40	40	0	0	3	32	9.83	7.38	2	19	6.15	4.19	2	16	5.48	3.60
G	16	H, I, K	22	24	38	40	2	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
H	6	M	40	53	46	59	13	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
I	11	L	40	40	51	51	0	0	3	18	6.79	5.21	3	15	6.06	3.72	3	14	5.85	3.72
J	19	L	26	32	45	51	6	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	15	T/O	40	54	55	69	14	14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
L	18	T/O	51	51	69	69	0	0	3	32	10.69	8.36	2	18	6.60	4.75	1	15	5.17	4.04
M	10	T/O	46	59	56	69	13	13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T/O	3	N/A	69	69	72	72	0	0	3	4	3.50	0.00	6	9	7.56	0.37	9	12	11.07	0.69
Grand Average Across Activities									3.0	18.0	6.55	4.63	3.4	14.9	6.19	3.36	3.9	14.6	6.58	3.33

Thompson and Lucko (2011)

Performance for Three Allocation Mechanisms







Results

- Plotting float overrun over *CF* for three mechanisms
- Shapes represent efficacy of delay mitigation:
  - 'Plateau': Low *CF*, some critical activities consume more than they own or may not even have *DF* yet
  - 'Cliff': Float shows powerful absorption of delays
  - 'Bottom': Activities within their *DF* even if delayed; project has minimum prob. of exceeding deadline
  - 'Beyond': Excess *DF*, project could be shorter
- Describing 'cliff': L edge, R edge, mean *m* and standard deviation *s* (weighted as cliff is stepped)
  - n^0,$n^{0.5}$,n1: {3.0-18.0, 3.4-14.9, 3.9-14.6} = {15, 11.5, 10.7}
  - m = {6.55, 6.19, 6.58} not sign. diff., s = {4.63, 3.36, 3.33}

Conclusions

- Vision for overcoming paradigm of float ownership
  - Targets critical activities, but DF remains at project end
  - Unambiguous and preventive
  - Fair and equitable – even risk
  - → *DF* as tradable commodity (de la Garza *et al.* 1991)

- Recommendations for future research
  - Duration, cost, risk as combined input
  - More large examples, other distributions
  - Rounding challenge (different methods)
  - Measure instances and severity of overrun
  - Monetary valuation in market of opportunities

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Thank you!

Do you have
any questions?

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