3rd International Conference on Project Evaluation 2016 icopev

University of Minho
School of Engineering

Project Management Under Uncertainty: solution methods revisited

João Faria, Madalena Araújo and Anabela Tereso
Department of Production and Systems Engineering
ALGORITMI Centre – University of Minho – Portugal

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Introduction

- Project - onetime endeavor aiming to reach a predefined goal.
- Imperative - project manager (and team) - necessary skills - best tools - get it right the first time.
- Project managers face increasing challenges - projects become more complex - higher levels of uncertainty.
- This collides with - demand to deliver on time - without additional costs.
- Method at hand - use the available resources to work more within the same time unit:
  - additional costs (overtime) or
  - no additional cost managed in an ad-hoc way.

Need for further support to project managers to cope with these increasing demands.

The problem

- **How can a project manager develop and control a plan that is duration minimal and is simultaneously able to cope with uncertainties?**

- Divide the question such that the plan can cope with uncertainty:
  - What is the impact in the project duration regarding the scheduling technique used?
  - How can an optimal or near optimal schedule be produced to cope with uncertainty?

  (Focus: address the first question)

Literature review

Dealing with uncertainty:

- PERT: no resource constraints (insufficient to model most "real world" projects);
- Optimization of resource allocation in projects considering stochastic work contents;
- RCPSP: unable to cope with uncertainties (fixed duration activities);
- SRCPSP: optimizes coping with random activity duration but has no baseline schedule;
- Proactive/Reactive scheduling:
  - Proactive: generate a robust baseline schedule (robust resource allocation, buffer insertion);
  - Reactive: correct the schedule if disruptions occur.

The method to explore

Methodology

To assess the impact of the scheduling model in the resources allocated to a project, the following parameters were used:

- Testset: psplib J30 (RCPSP) instances;
- Solution methods:

- Optimal solutions: DH branch and bound algorithm.

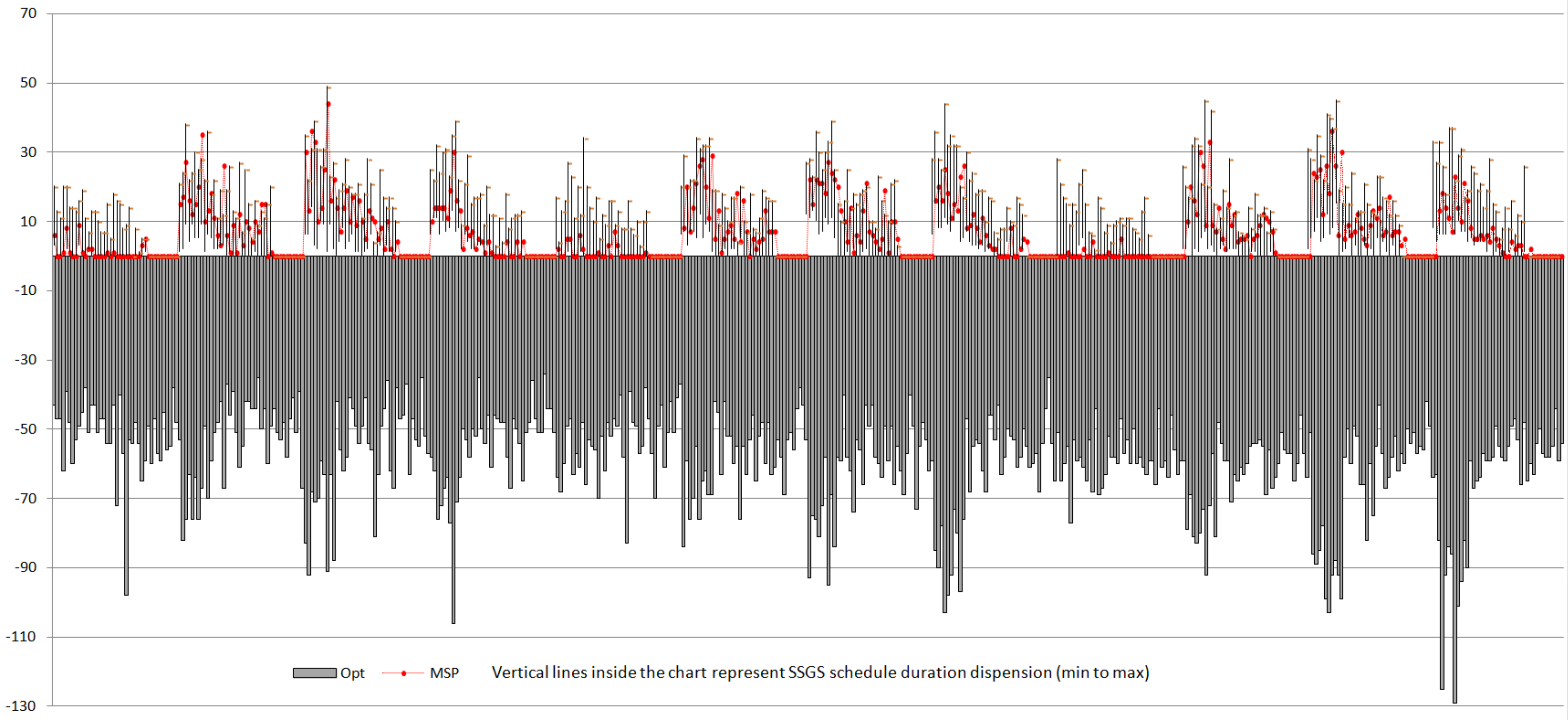
- Heuristic method: SSGS (Serial Scheduling Generation Scheme) with the priority rules:

LJN (Lowest Job Number);
SPT (Shortest Processing Time);
MIS (Most Immediate Successors);
LNRJ (Least Number of Related Jobs);
EST (Earliest Start Time);
LST (Latest Start Time);
MSLK (Minimum Slack);
GCRWC (Greatest Cumulative Resource Work Content).
RND (Random);
LPT (Longest Processing Time);
MTS (Most Total Successors);
GRPW (Greatest Rank Positional Weight);
EFT (Earliest Finish Time);
LFT (Latest Finish Time);
GRWC (Greatest Resource Work Content);

- Comercial tool: Microsoft Project 2013.

Note: All implemented solution methods were coded in Microsoft Visual C++ 2012

Results: Project duration span



Project duration summary

Optimal duration is used as reference	Optimal duration	Deviation from optimal duration															
		SSGS with defined priority rule															MSProject
		LJN	RND	SPT	LPT	MIS	MTS	LNRJ	GRPW	EST	EFT	LST	LFT	MSLK	GRWC	GCRWC	
Max	129	37	45	49	39	36	26	34	36	31	37	30	30	39	39	35	44
Average	59	5,96	7,83	10,55	7,71	6,11	4,22	6,71	6,50	5,74	7,25	3,31	3,67	6,12	7,39	6,72	6,13
Min	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max%		44%	63%	57%	51%	48%	32%	49%	52%	44%	46%	33%	34%	49%	60%	57%	53%
Average%		9%	13%	17%	12%	10%	7%	11%	10%	9%	12%	5%	6%	9%	12%	11%	9%
Min%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Max=$(\max_i(d_i - d_{opt}))$ Average=$\left(\frac{\sum_i(d_i-d_{opt})}{480}\right)$ Min=$(\min_i(d_i - d_{opt}))$

Max%=$(\max_i(d_i - d_{opt})/ d_{opt})$ Average%=$\left(\frac{\sum_i(d_i-d_{opt})/d_{opt}}{480}\right)$ Min%=$(\min_i(d_i - d_{opt})/d_{opt})$

Average resources

	Required				Available				% Unused ($\frac{\text{Available} - \text{Required}}{\text{Available}}$)			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R4	R3	R4
Optimal	570,66	583,46	574,56	581,99	1160,78	1171,60	1161,13	1161,61	52,00%	51,50%	51,96%	50,78%
Best SSGS	570,66	583,46	574,56	581,99	1191,42	1202,88	1192,46	1192,24	53,54%	53,05%	53,48%	52,36%
MSProject	570,66	583,46	574,56	581,99	1263,46	1276,71	1265,40	1264,40	56,42%	55,97%	56,40%	55,27%

Conclusions

- Results show that the scheduling solution method greatly influences the project's duration - the most commonly used scheduling techniques present poor results even considering small projects.

- Even using non-optimal schedules, projects do, more than often, overrun their estimated duration, while having unused resources (not available at the right time).

- This means that additional efforts are needed to make them more resistant to failure - make them more robust.

- This study is a starting point to address the problem of transforming a given schedule into a more robust one to attain better behavior when unforseen events occur during project execution.

Future work

- Schedule robustness can be enhanced by combining the concepts of Flexible Resources and Proactive/Reactive scheduling …
- … by redistributing resources in order to accelerate critical activities at the expense of slowing down non-critical activities.
- Achieved by keeping activity start times - assuming that resources are "flexible" - their "per unit of time" work capacity can vary from their predefined nominal value (a_k^{nom}).

$$a_k^{nom}(1-\alpha_k^-) \leq a_k \leq a_k^{nom}(1+\alpha_k^+)$$

a_k is the effective resource availability;

α_k^- / α_k^+ is the maximal decrease/increase of resource k availability per time unit.

- Slow down activities with slack by using its resources in a reduced availability mode - critical activities executed at a faster rate - using its resources at an increased availability mode.
- Critical activities will have then a time buffer that can be used to cope with eventual increases in their work content to avoid them to delay the project.

References

1. Ballestín, F., Leus, R., 2009. Resource-Constrained Project Scheduling for Timely Project Completion with Stochastic Activity Durations. Prod. Oper. Manag. 18, 459–474. doi:10.1111/j.1937-5956.2009.01023.x
2. Birbil, S.I., Fang, S.C., 2003. An electromagnetism-like mechanism for global optimization. J. Glob. Optim. 25, 263–282. doi:10.1023/a:1022452626305
3. Couto, J., 2012. Identifying factors for the poor public institutions performance in portuguese construction industry. Int. J. Acad. Res. Vol. 3, Issue 3, May, part 1, pp. 252-257. doi:http://hdl.handle.net/1822/16346
4. Couto, J., Teixeira, J., 2007. The Evaluation of the Delays in the Portuguese Construction. CIB World Build. Congr.
5. Demeulemeester, E., Herroelen, W., 2009. Robust Project Scheduling, Foundations and Trends® in Technology, Information and Operations Management. now Publishers Inc. doi:10.1561/0200000021
6. Demeulemeester, E., Herroelen, W., 2002. Project Scheduling: A Research Handbook. Springer. doi:10.1007/b101924
7. Demeulemeester, E., Herroelen, W., 1997. New Benchmark Results for the Resource-Constrained Project Scheduling Problem. Manage. Sci. 43, 1485–1492.
8. Demeulemeester, E., Herroelen, W., 1992. A Branch-and- Bound Procedure for the Multiple Resource- Constrained Project Scheduling Problem. Manage. Sci. 38, 1803–1818. doi:doi:10.1287/mnsc.38.12.1803
9. Elmaghraby, S., 2005. On the fallacy of averages in project risk management. Eur. J. Oper. Res. 165, 307–313. doi:10.1016/j.ejor.2004.04.003
10. Elmaghraby, S., Morgan, C., 2007. Resources Allocation in Activity Networks Under Stochastic Conditions: A Geometric Programming-Sample Path Optimization Approach. Tijdschr. voor Econ. en Manag. 52, 367.
11. Flyvbjerg, B., Bruzelius, N., Rothengatter, W., 2003. Megaprojects and Risk: An Anatomy of Ambition. Cambridge University Press.
12. Goldratt, E.M., 1997. Critical chain. North River Press, Great Barrington, MA.
13. Herroelen, W., Leus, R., 2004. Identification and illumination of popular misconceptions about project scheduling and time buffering in a resource-constrained environment. J. Oper. Res. Soc. 56, 102–109. doi:10.1057/palgrave.jors.2601813
14. Jia, J., Fan, X., Lu, Y., 2007. System Dynamics Modeling for Overtime Management Strategy of Software Project. 2007, Int. Syst. Dyn. Conf.
15. Kolisch, R., 1996. Serial and parallel resource-constrained project scheduling methods revisited: Theory and computation. Eur. J. Oper. Res. 90, 320–333. doi:http://dx.doi.org/10.1016/0377-2217(95)00357-6
16. Kolisch, R., Sprecher, A., 1997. PSPLIB - A project scheduling problem library. Eur. J. Oper. Res. 96, 205– 216. doi:10.1016/S0377-2217(96)00170-1
17. Naber, A., Kolisch, R., 2014. MIP models for resource-constrained project scheduling with flexible resource profiles. Eur. J. Oper. Res. 239, 335–348. doi:http://dx.doi.org/10.1016/j.ejor.2014.05.036
18. Olsen, B., Swenson, D., 2011. Overtime Effects on Project Team Effectiveness. Midwest Instr. Comput. Symp.
19. Peteghem, V. Van, Vanhoucke, M., 2010. A genetic algorithm for the preemptive and non-preemptive multi-mode resource-constrained project scheduling problem. Eur. J. Oper. Res. 201, 409–418. doi:http://dx.doi.org/10.1016/j.ejor.2009.03.034
20. Santos, M., Tereso, A., 2011. On the Multi-mode, Multi-skill Resource Constrained Project Scheduling Problem - A Software Application. Soft Comput. Ind. Appl. 96, 239–248.
21. Schatteman, D., Herroelen, W., Van de Vonder, S., Boone, A., 2008. Methodology for Integrated Risk Management and Proactive Scheduling of Construction Projects. J. Constr. Eng. Manag. 134, 885–893. doi:10.1061/(asce)0733-9364(2008)134:11(885)
22. Silva, H., Oliveira, J., Tereso, A., 2011. A genetic algorithm for project scheduling in activity networks under resource complementarity. doi:http://hdl.handle.net/1822/15524
23. Silva, H., Oliveira, J., Tereso, A., 2010. On resource complementarity in activity networks. doi:http://hdl.handle.net/1822/19367
24. Stork, F., 2001. Stochastic Resource-Constrained Scheduling. PhD Thesis. Technische Universität Berlin.
25. Tereso, A., 2002. Gestão de projectos: alocação adaptativa de recursos em redes de actividades multimodais. doi:http://hdl.handle.net/1822/39
26. Tereso, A., Araújo, M., Elmaghraby, S., 2004. Adaptive resource allocation in multimodal activity networks. Int. J. Prod. Econ. 92, 1–10. doi:10.1016/j.ijpe.2003.09.005
27. Tereso, A., Araújo, M., Moutinho, R., Elmaghraby, S., 2008. Project management : multiple resources allocation. doi:http://hdl.handle.net/1822/8632
28. Tereso, A., Costa, L., Novais, R., Araújo, M., 2007. The optimal resource allocation in stochastic activity networks via the evolutionary approach : a platform implementation in Java, in: IESM 2007. doi:http://hdl.handle.net/1822/19366
29. Tereso, A., Mota, J.R., Lameiro, R., 2006. Adaptive resource allocation to stochastic multimodal projects: a distributed platform implementation in Java. Control Cybern. 35, 661–686.
30. Tereso, A., Novais, R., Araújo, M., Elmaghraby, S., 2009. Optimal resource allocation in stochastic activity networks via the electromagnetism approach: a platform implementation in Java. Control Cybern. 38.
31. The Standish Group, 2014. Chaos Summary 2014.
32. The Standish Group, 2009. Chaos Summary 2009 1–4.
33. Tian, W., Demeulemeester, E., 2010. Railway scheduling reduces the expected project makespan. Kathol. Univ. Leuven KBI 1004.
34. Van de Vonder, S., Demeulemeester, E., Herroelen, W., Leus, R., 2005. The use of buffers in project management: The trade-off between stability and makespan. Int. J. Prod. Econ. 97, 227–240. doi:10.1016/j.ijpe.2004.08.004
35. Van de Vonder, S., Demeulemeester, E., Leus, R., Herroelen, W., 2006. Proactive-reactive project scheduling trade-offs and procedures, in: Perspectives in Modern Project Scheduling. Springer, pp. 25–51.