

Supplementary Materials

Forecasting the Project Duration Average and Standard Deviation from Deterministic Schedule Information

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Supplementary A: Real projects dataset characteristics summary and project activity durations log means and log standard deviations

Table S1 on the next page presents the 101 real projects dataset most relevant information: the original OR-AS project ID codes; the project names and project types (building, civil engineering, industrial or services); planned and actual (as-built) overall project costs and durations; and the number of activities per project. The last four columns summarize the average activity log-durations and log-standard deviations from which datasets V to VIII took their (extreme) moment values.

Table S1. Real projects dataset summary.

ID	Project Name	Type	Project Cost (10 ³ €)		Proj. Dur. (days)		N° Activ.	LN (planned <i>d_i</i>)		LN (actual <i>d_i</i>)		SP (%)
			Planned	Actual	Planned	Actual		μ	σ	μ	σ	
C2011-05	Telecom System Agnes	Service	180.49	180.49	43	53	20	1.07	1.01	1.07	1.01	60
C2011-07	Patient Transport System	Service	180.76	191.07	389	444	49	0.87	0.72	0.96	0.73	70
C2011-10	Building a House	Building	484.40	494.95	195	203	32	1.85	0.97	1.85	1.02	51
C2011-12	Claeys-Verhelst Premises	Building	3,027.13	3,102.40	443	453	49	2.59	0.76	2.65	0.82	41
C2011-13	Wind Farm	Civil Eng.	21,369.84	26,077.76	525	600	107	1.78	1.03	1.89	1.00	27
C2012-13	Pumping Station Jabbeke	Industrial	336.41	350.51	125	140	74	0.62	0.79	0.51	0.72	64
C2012-15	The Master Project	Service	185.47	185.11	32	32	121	1.08	0.42	1.00	0.49	17
C2012-17	Building a Dream	Building	241.02	314.86	145	204	33	1.29	0.72	1.63	0.84	65
C2013-01	Wiedauwkaai Fenders	Civil Eng.	1069.53	1,314.58	152	152	39	1.55	1.04	1.63	1.16	48
C2013-02	Sewage Plant Hove	Civil Eng.	1236.60	1,146.44	403	408	175	1.90	0.69	1.89	0.72	12
C2013-03	Brussels Finance Tower	Building	15,440.87	16,338.03	425	426	55	3.56	1.28	3.51	1.09	3
C2013-04	Kitchen Tower Anderlecht	Building	2,113.68	2,512.52	333	453	244	0.47	0.80	0.38	0.81	47
C2013-05	PET Packaging	Service	874.55	874.55	521	632	28	4.46	0.76	4.50	0.82	14
C2013-06	Govmnt. Office Building	Building	19,429.81	21,546.85	352	344	275	1.87	0.73	1.94	0.74	10
C2013-07	Family Residence	Building	180.48	175.03	170	174	46	0.54	0.86	0.54	0.89	40
C2013-08	Timber House	Building	501.03	576.62	216	235	41	0.72	0.82	0.81	0.94	29
C2013-09	Urban Develop.Project	Civil Eng.	1,537.40	1,696.97	291	360	71	1.67	0.94	1.73	1.00	34
C2013-10	Town Square	Civil Eng.	11,421.89	15,218.93	786	785	186	1.46	1.10	1.49	1.06	18
C2013-11	Recreation Complex	Building	5,480.52	5,451.03	359	277	159	1.85	0.99	1.92	1.01	27
C2013-12	Young Cattle Barn	Building	818.44	879.85	115	188	27	2.03	0.74	2.04	0.55	64
C2013-13	Office Finish. Works (1)	Building	1,118.50	955.93	236	217	11	3.56	1.57	3.15	1.49	20
C2013-14	Office Finish. Works (2)	Building	85.85	75.47	80	88	9	1.40	1.53	1.29	1.32	62
C2013-15	Office Finish. Works (3)	Building	341.47	308.34	171	115	17	2.71	1.16	2.88	0.96	25
C2013-16	Office Finish. Works (4)	Building	248.20	198.57	196	108	7	2.87	2.04	3.93	0.65	33
C2013-17	Office Finish. Works (5)	Building	244.21	203.61	161	107	23	2.30	1.68	2.08	1.44	36
C2014-01	Mixed-use Building	Building	38,697.82	39,777.64	474	448	41	3.40	0.93	3.22	1.09	50
C2014-02	Playing Cards	Industrial	191.49	190.27	124	146	21	1.75	1.14	1.80	1.20	81

C2014-03	Organizational Develop.	Service	43.17	83.71	229	260	112	1.35	1.45	2.00	1.48	9
C2014-04	Compres. Station Zelzate	Industrial	62,385.60	65,526.93	522	844	24	3.08	0.05	3.13	0.85	95
C2014-05	Apartment Building (1)	Building	532.41	591.41	228	274	25	2.18	1.04	2.37	1.00	58
C2014-06	Apartment Building (2)	Building	3,486.38	3,599.11	547	611	29	2.78	1.35	2.81	1.40	57
C2014-07	Apartment Building (3)	Building	1,102.54	1,289.70	353	404	25	2.68	1.16	2.90	1.10	58
C2014-08	Apartment Building (4)	Building	1,992.22	2,380.30	233	275	39	2.01	0.60	2.24	0.63	44
C2015-01	Young Cattle Barn (2)	Building	612.77	646.47	131	210	27	1.71	1.01	1.88	0.77	57
C2015-02	Railway Station (1)	Civil Eng.	1,121.32	967.99	417	501	216	1.57	1.88	2.33	1.09	8
C2015-03	Industrial Complex (1)	Building	2,244.09	1,868.80	257	278	134	1.56	0.90	1.52	0.82	16
C2015-04	Apartment Building (5)	Building	2,750.94	2,590.80	160	205	56	1.63	0.19	1.72	0.54	27
C2015-06	Family Residence (2)	Building	143.67	186.11	260	290	184	2.03	0.56	2.06	0.63	18
C2015-07	Industrial Complex (2)	Building	5,999.60	5,414.54	297	313	138	1.74	1.10	1.59	1.11	27
C2015-08	Garden Center	Building	467.30	461.90	191	186	186	0.66	0.71	0.67	0.70	14
C2015-09	Railway Station (2)	Civil Eng.	1,457.42	2,145.68	354	569	340	1.86	1.49	2.37	1.13	4
C2015-10	Tax Return System (1)	Service	18.99	8.01	85	85	15	0.77	0.49	0.71	0.65	10
C2015-11	Staff Authoriz. System	Service	14.40	9.11	55	55	7	1.06	0.60	0.60	0.69	25
C2015-12	Premium Payment System	Service	132.57	58.41	184	184	35	1.53	0.81	0.97	0.77	19
C2015-13	Broker Acc.Conv. System	Service	12.74	9.99	117	117	16	0.48	0.54	0.71	0.63	19
C2015-14	Sup. Pensions Database	Service	34.26	18.29	124	124	17	0.98	0.75	0.85	0.70	17
C2015-15	FACTA System	Service	11.70	7.04	57	57	13	0.61	0.62	0.33	0.45	22
C2015-16	Generic Doc. Output Syst.	Service	64.62	64.13	270	270	22	1.44	0.71	1.37	0.83	10
C2015-17	Insurance Bundling Syst.	Service	281.43	281.07	208	236	86	1.50	0.88	1.42	0.95	6
C2015-18	Tax Return System (2)	Service	39.45	25.38	128	128	15	1.25	0.78	0.93	0.87	10
C2015-19	Receipt Numb. System	Service	43.80	37.53	182	182	18	1.06	0.97	0.93	1.00	21
C2015-20	Policy Numbering System	Service	12.65	11.10	171	161	6	1.04	0.74	0.94	0.76	20
C2015-21	Investment Product (1)	Service	4.02	3.24	37	37	12	0.75	0.69	0.60	0.67	18
C2015-22	Risk Profile Questionnaire	Service	29.88	17.40	151	151	22	0.75	0.68	0.47	0.57	16
C2015-23	Investment Product (2)	Industrial	46.92	32.81	122	120	33	0.97	0.60	0.73	0.70	17
C2015-24	CRM System	Service	44.13	36.87	233	233	21	1.04	0.87	0.95	0.82	7
C2015-25	Beer Tasting	Service	1.21	1.78	14	14	18	0.68	0.83	0.88	1.01	16
C2015-26	Debt Collection System	Service	458.11	512.55	148	154	214	0.81	0.83	0.83	0.88	9
C2015-27	Railway Station Antwerp	Building	22.70	25.31	68	81	18	1.23	0.91	1.27	0.97	23
C2015-28	Web. Tennis Vlaanderen	Service	219.28	382.48	201	212	20	1.59	1.54	1.95	1.70	15
C2015-29	Fire Station	Building	1,874.50	1,887.09	284	298	204	0.96	0.85	0.96	0.84	48
C2015-30	Social Apts. Ypres (1)	Building	440.94	440.94	244	254	40	1.81	0.91	1.86	0.86	25
C2015-31	Social Apts Ypres (2)	Building	1,310.72	1,282.19	271	364	29	2.72	1.23	2.65	1.22	32
C2015-32	Social Apts Ypres (3)	Building	2,509.03	2,509.03	358	265	48	2.53	0.88	2.27	0.88	38
C2015-33	IJzertoren Memor. Square	Civil Eng.	214.42	224.79	50	94	12	1.84	0.34	1.42	0.93	63
C2015-34	Roadworks Poperinge	Civil Eng.	511.33	440.39	120	193	13	2.57	0.73	2.03	0.92	91
C2015-35	Retirement Apartments	Building	14,956.31	16,068.88	850	951	11	5.34	0.80	5.42	0.90	48
C2016-01	Railway Bridge (1)	Civil Eng.	671.38	703.70	225	274	26	1.80	0.85	1.84	0.93	51
C2016-02	Railway Bridge (2)	Civil Eng.	962.18	972.34	229	239	23	1.42	1.22	1.34	1.29	63
C2016-03	Railway Bridge (3)	Civil Eng.	926.89	910.73	203	220	25	1.79	1.04	1.68	0.99	16
C2016-04	Railway Bridge (4)	Civil Eng.	906.25	906.25	248	242	26	1.61	1.04	1.61	1.04	64
C2016-05	Railway Bridge (5)	Civil Eng.	832.50	832.50	195	197	32	1.59	1.02	1.59	1.02	77
C2016-06	Defense Building	Service	4,331.26	4,331.26	252	232	96	1.93	0.92	1.93	0.92	14
C2016-07	Shop. Village Walkways	Civil Eng.	930.18	932.76	224	316	110	2.14	0.42	2.07	0.41	95
C2016-08	SCM System	Service	375.25	438.74	725	725	99	2.58	0.90	2.67	0.88	49
C2016-09	Data Loss Prevent. System	Service	584.95	1,425.16	195	189	113	0.95	0.58	1.21	0.87	10
C2016-10	Biofuel Refinery	Industrial	14,362.63	14,466.10	360	375	23	3.99	1.32	4.15	1.26	18
C2016-11	Residential House (1)	Building	162.47	163.19	241	254	55	1.26	0.95	1.29	0.96	57
C2016-12	Residential House (2)	Building	222.86	226.29	291	291	59	1.47	1.00	1.48	1.01	56
C2016-13	Residential House (3)	Building	367.95	379.30	306	330	51	1.63	0.82	1.66	0.88	64
C2016-14	Residential House (4)	Building	218.37	222.02	321	320	48	1.59	1.00	1.60	1.02	68
C2016-15	Resid. House Struct. Work	Building	95.69	100.76	126	130	13	1.96	1.06	2.09	0.94	66
C2016-16	Resid. Finish. Works (1)	Building	54.58	64.53	90	90	24	1.64	0.14	1.64	0.14	69
C2016-17	Resid. Finish. Works (2)	Building	54.70	64.58	86	86	24	1.57	0.36	1.57	0.36	69
C2016-18	Resid. Finish. Works (3)	Building	51.12	60.83	91	91	25	1.57	0.36	1.57	0.36	66
C2016-19	Resid. Finish. Works (4)	Building	51.30	53.35	91	91	25	1.57	0.36	1.57	0.36	66
C2016-20	Resid. Finish. Works (5)	Building	52.02	53.78	91	91	25	1.57	0.36	1.57	0.36	66
C2016-21	Resid. Finish. Works (6)	Building	54.32	55.00	101	101	24	1.74	0.49	1.74	0.49	69
C2016-22	Resid. Finish. Works (7)	Building	56.97	57.82	101	101	24	1.74	0.49	1.74	0.49	69
C2016-23	Resid. Finish. Works (8)	Building	56.18	56.65	101	101	24	1.74	0.49	1.74	0.49	69
C2016-24	Resid. Finish. Works (9)	Building	52.26	53.18	101	101	24	1.74	0.49	1.74	0.49	69
C2016-25	Resid. Finish. Works (10)	Building	54.58	56.75	91	91	24	1.60	0.39	1.60	0.39	69
C2016-26	Resid. Finish. Works (11)	Building	51.29	53.32	91	91	24	1.60	0.39	1.60	0.39	69

C2016-27	Apt. Build. Foundat. (1)	Building	813.66	879.70	78	88	16	1.74	0.75	1.91	0.68	66
C2016-28	Apt. Struct. Work (1)	Building	569.18	586.09	71	79	19	1.87	0.57	1.94	0.62	55
C2016-29	Apt. Struct. Work (2)	Building	1,797.87	1,860.33	129	148	19	2.10	0.61	2.15	0.65	72
C2016-30	Apt. Struct. Work (3)	Building	1,319.74	1,353.36	85	96	23	1.75	0.50	1.78	0.56	81
C2016-31	Apt. Struct. Work (1)	Building	488.94	498.47	105	117	23	2.23	0.53	2.35	0.47	31
C2016-32	Apt. Struct. Work (2)	Building	477.38	496.99	89	97	22	2.08	0.50	2.24	0.42	52
C2016-33	Apt. Struct. Work (3)	Building	377.28	394.83	116	129	23	2.21	0.52	2.34	0.47	50
C2016-34	Apt. Struct. Work (4)	Building	362.48	383.87	83	92	23	2.01	0.52	2.15	0.46	40
Avg.			2,647.86	2,837.45	221	240	56.38	1.75	0.83	1.77	0.83	41

Supplementary B: 4100-project schedule networks and datasets regression results

The original 4100-project schedule dataset was developed by the Ghent University Operations Research & Scheduling Research Group (OR-AS) and can be downloaded here: <http://www.projectmanagement.ugent.be/research/data/RanGen> (MT set). From each network (project), a file can be found containing all predecessors' activity information.

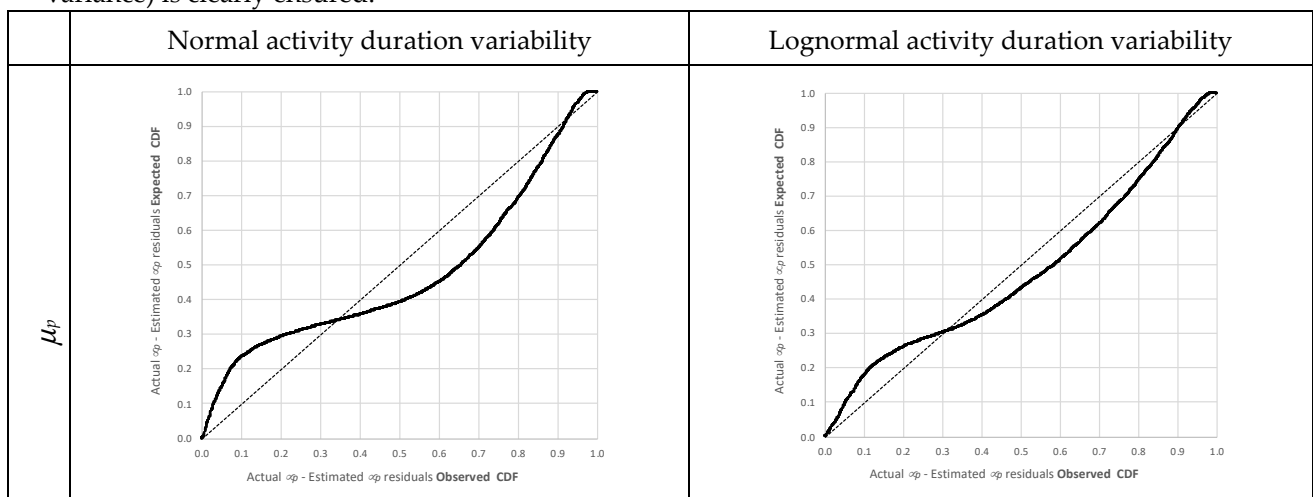
The μ_p and σ_p regression results from the 13 datasets can be accessed here: <http://bit.ly/33l2zSl>. This link corresponds to a 177 MB MS Excel file. Please, be patient when downloading and opening it. This file contains multiple tabs:

4100-project database: contains all network instances

Dataset results (tabs I to XIII): contain the results for the 13 network dataset configurations. All actual and estimated μ_p and σ_p values are included, along with all the deterministic schedule information (Planned Duration PD , activity durations d_i , activity duration standard deviations σ_i and/or coefficients of variation CV_i , activity total slacks s_i , and activity free slacks s'_i). The latter allows any researcher to fully reproduce our results.

Supplementary C: Dataset I μ_p and σ_p regression QQ plots and homoscedasticity graphs

The following figures complement Figure 2 graphs presented in the paper. These graphs ensure that the Normality assumption is relatively tenable, whereas the homoscedasticity (homogeneous variance) is clearly ensured.



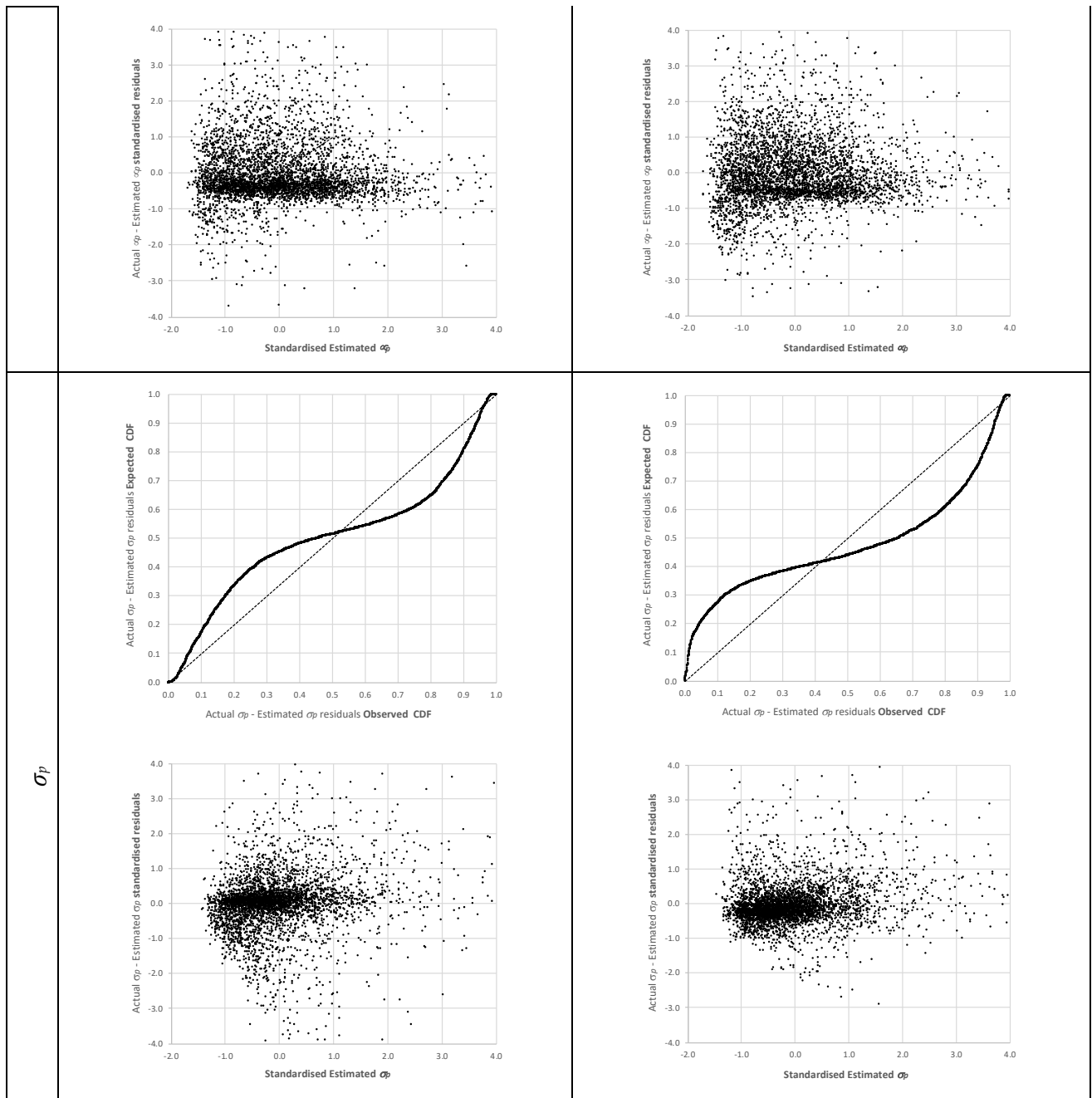


Figure S1. Dataset I μ_p (up) and σ_p (down) regressions QQ plots (upmost position within each box) and homoscedasticity graphs (downmost position within each box) when activity duration variability is Normal (left) and Lognormal (right)

Supplementary D: Summary of all datasets μ_p and σ_p regression results with free K_1 and K_2

In the Results section of the paper, Tables 3 and 4 presented the performance of expressions 9 and 12 for the 13 dataset configurations. However, in those results, either $K_1 = 1.12$ and $K_2 = -0.22$ (for symmetrical activity duration variability), or $K_1 = 1.22$ and $K_2 = +0.07$ (for asymmetrical activity duration variability). That is, these coefficients took on constant values in each expression depending on the type of distribution variability. In the following tables S2 and S3, we present how the performance of expressions 9 and 12, respectively, could have been improved by allowing coefficients K_1 and K_2 to vary freely when trying to minimize the MSE. As can be seen, with maybe the only arguable exception of p in the case of asymmetrical variability, the performance results are hardly improved compared to setting K_1 and K_2 to the constant values reported in Tables 3 and 4, respectively.

Table S2. Project duration estimates (μ_p/PD) performance results for the 13 project datasets when K_1 is set to minimize the MSE.

Dataset	Activity duration variability 1					Activity duration variability 2				
	R	R ²	K ₁	MAE ×10 ⁻³ (red.)	MSE ×10 ⁻³ (red.)	R	R ²	K ₁	MAE ×10 ⁻³ (red.)	MSE ×10 ⁻³ (red.)
I	0.91	0.83	1.17	4.4 (56%)	0.1 (88%)	0.92	0.85	1.29	18.8 (65%)	0.9 (84%)
II	0.90	0.81	1.03	1.3 (51%)	0.0 (87%)	0.92	0.85	1.16	5.0 (60%)	0.1 (82%)
III	0.92	0.84	1.18	7.8 (60%)	0.2 (94%)	0.96	0.92	1.27	26.5 (74%)	1.5 (86%)
IV	0.84	0.71	1.19	5.5 (43%)	0.1 (77%)	0.86	0.74	1.47	25 (49%)	1.6 (73%)
V	0.96	0.93	1.29	6.8 (76%)	0.2 (95%)	0.96	0.93	1.22	20.7 (76%)	1.3 (94%)
VI	0.91	0.83	1.11	4.1 (59%)	0.1 (92%)	0.95	0.90	1.20	16.5 (72%)	0.6 (85%)
VII	0.97	0.94	1.06	3.9 (77%)	0.1 (95%)	0.97	0.94	1.18	18 (78%)	0.9 (95%)
VIII	0.86	0.74	1.21	4.8 (44%)	0.1 (78%)	0.86	0.74	1.40	20.7 (52%)	1.3 (75%)
IX	0.97	0.93	1.02	3.3 (75%)	0.0 (96%)	0.97	0.94	1.13	16.1 (78%)	0.6 (95%)
X	0.97	0.93	0.92	0.9 (72%)	0.0 (96%)	0.97	0.95	1.03	3.7 (78%)	0.0 (94%)
XI	0.96	0.93	0.98	6.1 (76%)	0.1 (96%)	0.97	0.95	1.10	28.9 (79%)	1.9 (94%)
XII	0.95	0.90	1.07	4.0 (70%)	0.0 (94%)	0.96	0.93	1.18	18.2 (75%)	0.8 (92%)
XIII	0.96	0.93	1.31	7.0 (76%)	0.2 (95%)	0.96	0.93	1.23	20.9 (76%)	1.3 (94%)
Avg.	0.93	0.87	1.12	4.6 (64%)	0.1 (91%)	0.94	0.89	1.22	18.0 (70%)	1.0 (88%)

Table S3. Project duration standard deviation estimates (σ_p/k) performance results for the 13 project datasets when K_2 is set to minimize the MSE.

Dataset	Activity duration variability 1					Activity duration variability 2				
	R	R ²	K ₂	MAE ×10 ⁻³ (red.)	MSE ×10 ⁻³ (red.)	R	R ²	K ₂	MAE ×10 ⁻³ (red.)	MSE ×10 ⁻³ (red.)
I	0.77	0.59	-0.21	28.2 (26%)	2.2 (64%)	0.74	0.55	0.14	41.7 (22%)	8.1 (52%)
II	0.62	0.38	-0.22	18.4 (8%)	1.2 (44%)	0.74	0.55	-0.07	22.2 (16%)	1.3 (58%)
III	0.73	0.53	-0.24	32.9 (36%)	2.5 (66%)	0.82	0.67	0.19	34.6 (26%)	3.8 (67%)
IV	0.70	0.49	-0.19	30.8 (13%)	2.4 (49%)	0.74	0.55	0.10	44.4 (16%)	9.6 (50%)
V	0.93	0.86	-0.17	18.0 (64%)	1.0 (89%)	0.88	0.78	0.04	17.6 (37%)	1.1 (69%)
VI	0.77	0.60	-0.23	26.5 (33%)	1.9 (66%)	0.74	0.55	0.15	38.1 (29%)	7.8 (54%)
VII	0.92	0.85	-0.22	18.5 (65%)	1.0 (89%)	0.85	0.73	0.07	20.3 (36%)	1.3 (70%)
VIII	0.58	0.33	-0.18	29.4 (10%)	3.2 (38%)	0.72	0.52	0.11	45.8 (11%)	11.0 (45%)
IX	0.89	0.79	-0.25	19.9 (58%)	1.1 (83%)	0.87	0.76	0.09	24.0 (39%)	2.2 (72%)
X	0.91	0.82	-0.24	11.1 (58%)	0.3 (86%)	0.89	0.78	-0.13	13.2 (58%)	0.5 (84%)
XI	0.94	0.88	-0.26	19.1 (71%)	1.0 (91%)	0.91	0.82	0.10	13.7 (60%)	0.4 (87%)
XII	0.85	0.72	-0.30	23.7 (52%)	1.6 (78%)	0.77	0.59	0.10	33.2 (28%)	4.3 (53%)
XIII	0.92	0.85	-0.17	18.8 (63%)	1.0 (89%)	0.83	0.69	0.02	20.0 (28%)	1.7 (48%)
Avg.	0.81	0.67	-0.22	22.2 (43%)	1.6 (72%)	0.81	0.66	0.07	28.0 (31%)	4.1 (62%)

