CASE STUDY: THE WAREHOUSE PROJECT[1]

You are the successful contractor for a warehouse project. Based on the original bidding documents, you have developed the activity list shown in Table 1 which includes the activity number, the activity name, the activity duration, the set of predecessor activities, and the daily resource requirements.

The contract for this project requires completion within 28 working days after the *Notice to Proceed* and calls for liquidated damages for late completion at the rate of $1,000 per working day. The *General Conditions* of the contract include a clause identical to *SP-13* of the *U.S. Postal Service Specifications* (shown below). Following contract award, you submitted a computer printout of your master schedule that shows completion of the work in 28 working days.

At the time of the notice to proceed, the owner issues a *Change Order* and informs you that he has redesigned some of the work. This increases the duration of Activities 3, 7, 8, and 29 as follows:

Activity	Original Duration	New Duration	Duration Increase	Free Float (for comparison)
03-Fabricate interior wall partition [4C]	2d	8d	6d	15d
07-Fabricate exterior doors [2C]	2d	7d	5d	17d
08-Const. plywood ext. wall panel [4C]	3d	12d	9d	14d
29-Erect interior wall partitions [4C]	1d	4d	3d	4d

The owner agrees to pay the additional costs caused by the *Change Order* but refuses to allow any time extension. At this point, you become concerned about possible resource availability. **Each day you can only provide 4 carpenters (C), 4 ironworkers (I), and 4 laborers (L).**

Part 1

- Develop a schedule showing that you could complete the original project (before the *Change Order*) within 28 days without exceeding your resource availability constraints.
- Why do you think the owner denied granting the revised project any time extension?

Part 2

You now realize that you can no longer meet the 28-day schedule under the *Change Order* requirements. Thus, you accept the *Change Order* under protest, indicating that you do not agree with the owner's denial of time extension.

- How much time extension should you claim? Document your claim by producing a schedule using the revised activity duration estimates and subject to the above resource availability constraints. Knowing that this schedule will be challenged by the owner's top engineering talent, you must develop the shortest schedule possible.
- How much time extension should you claim if you could split activities?

Example 1: *General Services Administration* (GSA) Specification

"Adjustment of Contract Completion Time

The contractor acknowledges and agrees that actual delays in activities which, according to the computer-produced calendar-dated schedule, do not affect any contract completion date shown by the critical path in the network, do not have any effect on the contract completion date or dates and therefore will not be the basis for a change therein."

[1] Adapted by P.G. Ioannou from
"*Seabee Planner's and Estimator's Handbook*"
NavDocks-P-405, Dept. of the Navy, Bureau of Yards and Docks, Washington DC, circa 1960.

Example 2: *U.S. Postal Service* (USPS) Specification

"SP-13 Contractor-Prepared Network Analysis System* (NAS)*:

Float or slack is defined as the amount of time between the early start date, and the late start date, or the early finish date and the late finish date of any of the activities in the NAS schedule. Float or slack is not time for the exclusive use or benefit of either the Government or the Contractor. Extensions of time for performance required under the Contract General provisions entitled, "CHANGES", "DIFFERING SITE CONDITIONS", "TERMINATION FOR DEFAULT", "DAMAGES FOR DELAY", "TIME EXTENSIONS", OR "SUSPENSION OF WORK" will be granted only to the extent that equitable time adjustments for the activity or activities affected exceed the total float or slack along the channels involved."

TABLE 1. Activity List for Warehouse Project

MSP ID	P6 ID	Activity Name	Dur (d)	Predecessors	Resources
1	01	01-Site survey & material list	1		-
2	02	02-Material & equipment to site	3	1	-
3	03	03-Fabricate interior wall partition [4C]	2	2	4C
4	04	04-Fasten wood strips to purlins [2C]	2	2	2C
5	05	05-Fabricate timber trusses [4C]	4	2	4C
6	06	06-Excavate [4L]	1	2	4L
7	07	07-Fabricate exterior doors [2C]	2	2	2C
8	08	08-Const. plywood ext. wall panel [4C]	3	2	4C
9	09	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	6	4C, 2I, 2L
10	10	10-Place drain pipes [SUB]	1	6	SUB
11	11	11-Pour footings [1C,2L]	1	9	1C, 2L
12	12A	12A-Cure & strip footings (start)	3	11	-
13	13	13-Erect steel cols & vert brace [4I]	1	12B	4I
14	14	14-Backfill, compact & grade slab [2L]	2	10,12B	2L
15	15	15-Erect trusses [4I]	1	13,5	4I
16	16	16-Forms, rebar & drains floor slab [4C,2I]	1	14	4C, 2I
17	17	17-Fab & erect frames @ truss pans [2C,2I]	1	15	2C, 2I
18	18	18-Pour slab [1C,2L]	1	13,16	1C, 2L
19	19	19-Erect steel purlins [4I]	1	4,17	4I
20	20	20-Cure slab	6	18	-
21	21	21-Place red bridging & weld [4I]	1	19	4I
22	22	22-Erect ext. wall panels [4C]	2	20,8	4C
23	23	23-Nail planks to purlins [2C]	2	21	2C
24	24	24-Erect doors [2C]	1	7,22	2C
25	25	25-Waterproof & insulate joints [2L]	1	22	2L
26	26	26-Lay tar paper on planks [2L]	1	23	2L
27	27	27-Paint ext. walls [SUB]	2	24,25	SUB
28	28	28-Erect corrugated roofing [2C]	2	26	2C
29	29	29-Erect interior wall partitions [4C]	1	3,20,26	4C
30	30	30-Cleanup [4L]	2	27,28,29	4L
31	12B	12B-Cure & strip footings (end) [1L]	1	12A	1L

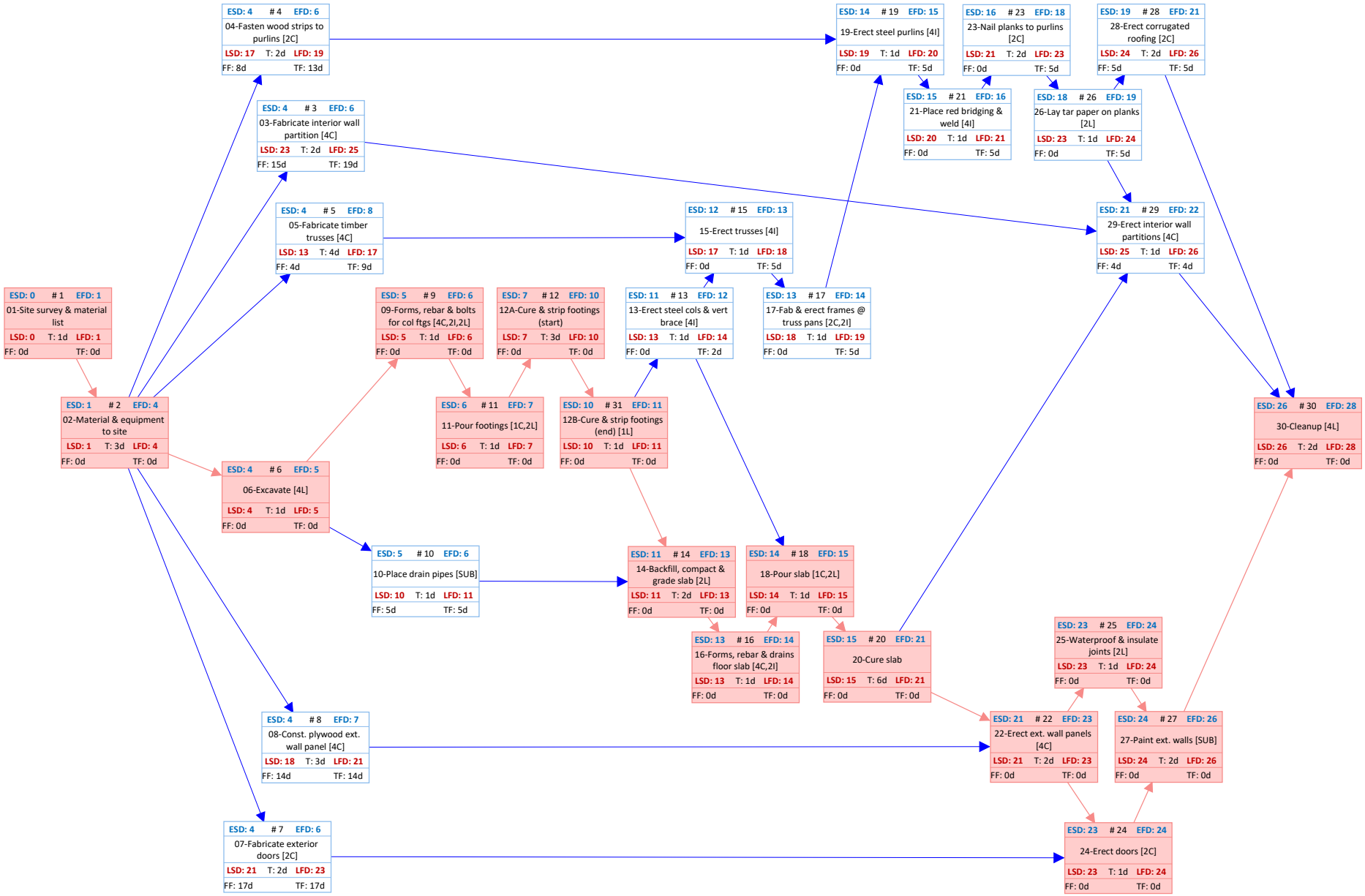
MSP ID: Activity ID numbers to use in MS Project Pro (consecutive numbers).
P6 ID: Activity ID numbers to use in P6 Pro (similar to the numbers used by Fondahl, P3, and Suretrak).

Note: The original Warehouse Project had only 30 activities, but also specified the following for activity 12:

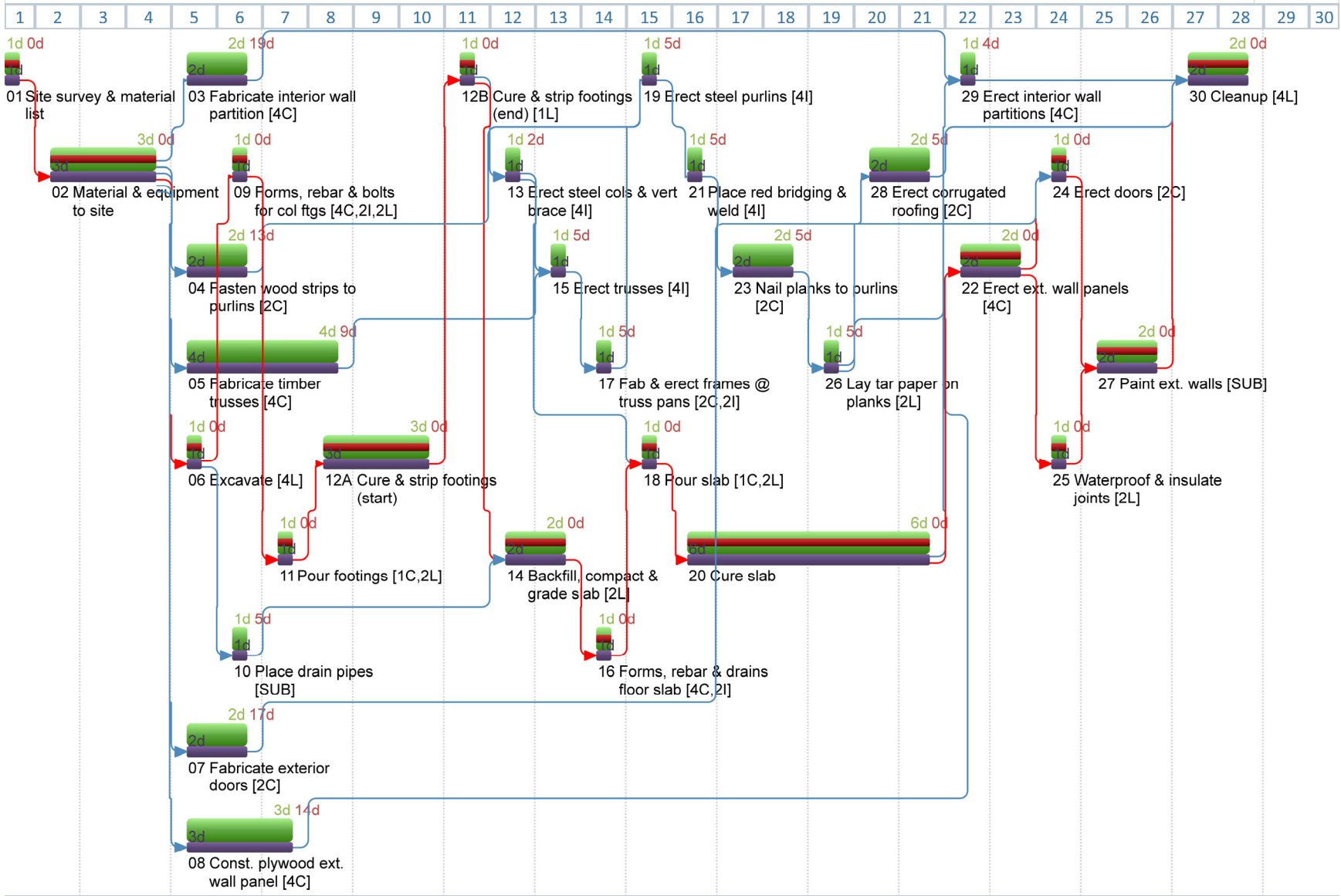
- "12 - Cure and strip footings"; T=4d; uses 1 Laborer, but only on the 4th day to strip the formwork.

This is modeled in Tables 1 & 2 by splitting activity 12 into two activities (with different resources) as follows:

- "12 or 12A - Cure and strip footings (start)"; T=3d (i.e., "Cure Footings"; no resources) and
- "31 or 12B - Cure and strip footings (end)"; T=1d (i.e., "Strip Footings"; 1L)


ESD: 0 # 1 EFD: 1
01-Site survey & material list
LSD: 0 T: 1d LFD: 1
FF: 0d TF: 0d
ESD: 4 # 4 EFD: 6
04-Fasten wood strips to purlins [2C]
LSD: 17 T: 2d LFD: 19
FF: 8d TF: 13d
ESD: 4 # 3 EFD: 6
03-Fabricate interior wall partition [4C]
LSD: 23 T: 2d LFD: 25
FF: 15d TF: 19d
ESD: 4 # 5 EFD: 8
05-Fabricate timber trusses [4C]
LSD: 13 T: 4d LFD: 17
FF: 4d TF: 9d
ESD: 1 # 2 EFD: 4
02-Material & equipment to site
LSD: 1 T: 3d LFD: 4
FF: 0d TF: 0d
ESD: 4 # 6 EFD: 5
06-Excavate [4L]
LSD: 4 T: 1d LFD: 5
FF: 0d TF: 0d
ESD: 5 # 9 EFD: 6
09-Forms, rebar & bolts for col ftgs [4C,2I,2L]
LSD: 5 T: 1d LFD: 6
FF: 0d TF: 0d
ESD: 6 # 11 EFD: 7
11-Pour footings [1C,2L]
LSD: 6 T: 1d LFD: 7
FF: 0d TF: 0d
ESD: 7 # 12 EFD: 10
12A-Cure & strip footings (start)
LSD: 7 T: 3d LFD: 10
FF: 0d TF: 0d
ESD: 10 # 31 EFD: 11
12B-Cure & strip footings (end) [1L]
LSD: 10 T: 1d LFD: 11
FF: 0d TF: 0d
ESD: 5 # 10 EFD: 6
10-Place drain pipes [SUB]
LSD: 10 T: 1d LFD: 11
FF: 5d TF: 5d
ESD: 4 # 8 EFD: 7
08-Const. plywood ext. wall panel [4C]
LSD: 18 T: 3d LFD: 21
FF: 14d TF: 14d
ESD: 4 # 7 EFD: 6
07-Fabricate exterior doors [2C]
LSD: 21 T: 2d LFD: 23
FF: 17d TF: 17d
ESD: 12 # 15 EFD: 13
15-Erect trusses [4I]
LSD: 17 T: 1d LFD: 18
FF: 0d TF: 5d
ESD: 11 # 13 EFD: 12
13-Erect steel cols & vert brace [4I]
LSD: 13 T: 1d LFD: 14
FF: 0d TF: 2d
ESD: 13 # 17 EFD: 14
17-Fab & erect frames @ truss pans [2C,2I]
LSD: 18 T: 1d LFD: 19
FF: 0d TF: 5d
ESD: 11 # 14 EFD: 13
14-Backfill, compact & grade slab [2L]
LSD: 11 T: 2d LFD: 13
FF: 0d TF: 0d
ESD: 14 # 18 EFD: 15
18-Pour slab [1C,2L]
LSD: 14 T: 1d LFD: 15
FF: 0d TF: 0d
ESD: 13 # 16 EFD: 14
16-Forms, rebar & drains floor slab [4C,2I]
LSD: 13 T: 1d LFD: 14
FF: 0d TF: 0d
ESD: 15 # 20 EFD: 21
20-Cure slab
LSD: 15 T: 6d LFD: 21
FF: 0d TF: 0d
ESD: 14 # 19 EFD: 15
19-Erect steel purlins [4I]
LSD: 19 T: 1d LFD: 20
FF: 0d TF: 5d
ESD: 15 # 21 EFD: 16
21-Place red bridging & weld [4I]
LSD: 20 T: 1d LFD: 21
FF: 0d TF: 5d
ESD: 16 # 23 EFD: 18
23-Nail planks to purlins [2C]
LSD: 21 T: 2d LFD: 23
FF: 0d TF: 5d
ESD: 18 # 26 EFD: 19
26-Lay tar paper on planks [2L]
LSD: 23 T: 1d LFD: 24
FF: 0d TF: 5d
ESD: 19 # 28 EFD: 21
28-Erect corrugated roofing [2C]
LSD: 24 T: 2d LFD: 26
FF: 5d TF: 5d
ESD: 21 # 29 EFD: 22
29-Erect interior wall partitions [4C]
LSD: 25 T: 1d LFD: 26
FF: 4d TF: 4d
ESD: 26 # 30 EFD: 28
30-Cleanup [4L]
LSD: 26 T: 2d LFD: 28
FF: 0d TF: 0d
ESD: 23 # 25 EFD: 24
25-Waterproof & insulate joints [2L]
LSD: 23 T: 1d LFD: 24
FF: 0d TF: 0d
ESD: 21 # 22 EFD: 23
22-Erect ext. wall panels [4C]
LSD: 21 T: 2d LFD: 23
FF: 0d TF: 0d
ESD: 24 # 27 EFD: 26
27-Paint ext. walls [SUB]
LSD: 24 T: 2d LFD: 26
FF: 0d TF: 0d
ESD: 23 # 24 EFD: 24
24-Erect doors [2C]
LSD: 23 T: 1d LFD: 24
FF: 0d TF: 0d

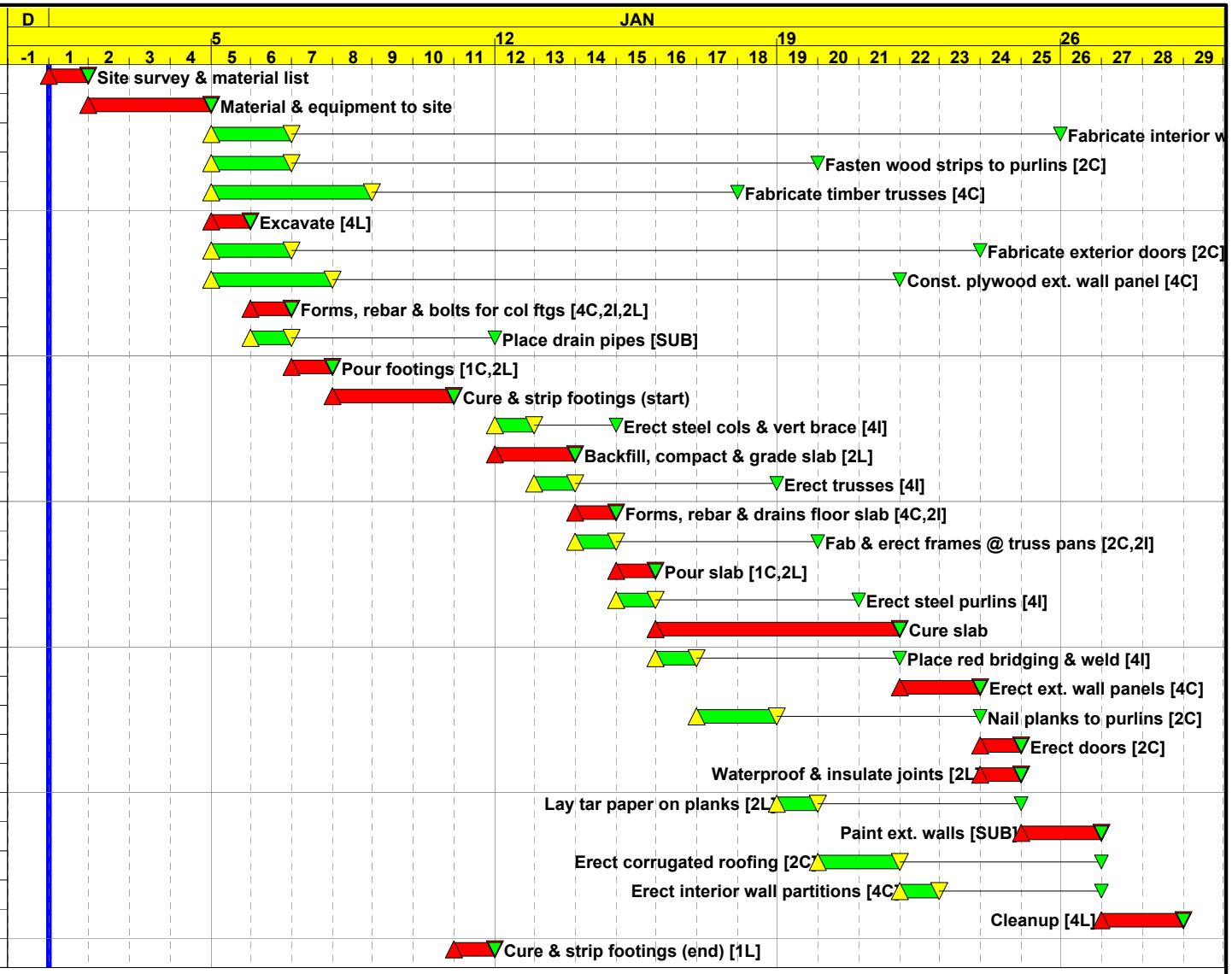
Primavera P6 Professional | 08-12-21



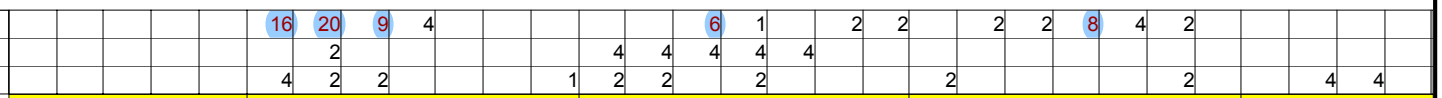
ID	Resource Name	Work	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	Unassigned	0d																								
1	**Carpenters**	**78d**	16d	20d	9d	4d						6d	1d		2d	2d		2d	2d	8d	4d	2d				
3	Laborers	27d	4d	2d	2d				1d	2d	2d		2d				2d					2d			4d	4d
2	Ironworkers	22d		2d						4d	4d	4d	4d	4d												

Course: CEE536 - CEE538 | Time-Scaled Logic Diagram | User: P.G. Ioannou

ID	Act	T	TF	FF
1	Site survey & material list	1	0	0
2	Material & equipment to site	3	0	0
3	Fabricate interior wall partition [4C]	2	19	15
4	Fasten wood strips to purlins [2C]	2	13	8
5	Fabricate timber trusses [4C]	4	9	4
6	Excavate [4L]	1	0	0
7	Fabricate exterior doors [2C]	2	17	17
8	Const. plywood ext. wall panel [4C]	3	14	14
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	0	0
10	Place drain pipes [SUB]	1	5	5
11	Pour footings [1C,2L]	1	0	0
12	Cure & strip footings (start)	3	0	0
13	Erect steel cols & vert brace [4I]	1	2	0
14	Backfill, compact & grade slab [2L]	2	0	0
15	Erect trusses [4I]	1	5	0
16	Forms, rebar & drains floor slab [4C,2I]	1	0	0
17	Fab & erect frames @ truss pans [2C,2I]	1	5	0
18	Pour slab [1C,2L]	1	0	0
19	Erect steel purlins [4I]	1	5	0
20	Cure slab	6	0	0
21	Place red bridging & weld [4I]	1	5	0
22	Erect ext. wall panels [4C]	2	0	0
23	Nail planks to purlins [2C]	2	5	0
24	Erect doors [2C]	1	0	0
25	Waterproof & insulate joints [2L]	1	0	0
26	Lay tar paper on planks [2L]	1	5	0
27	Paint ext. walls [SUB]	2	0	0
28	Erect corrugated roofing [2C]	2	5	5
29	Erect interior wall partitions [4C]	1	4	4
30	Cleanup [4L]	2	0	0
12B	Cure & strip footings (end) [1L]	1	0	0



Row	Group Name
1	Carpenters
2	Ironworkers
3	Laborers



Start Date 01JAN98
Finish Date 28JAN98
Data Date 01JAN98
Run Date 19JUN03 14:35

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Early Bar
Float Bar
Progress Bar
Critical Activity

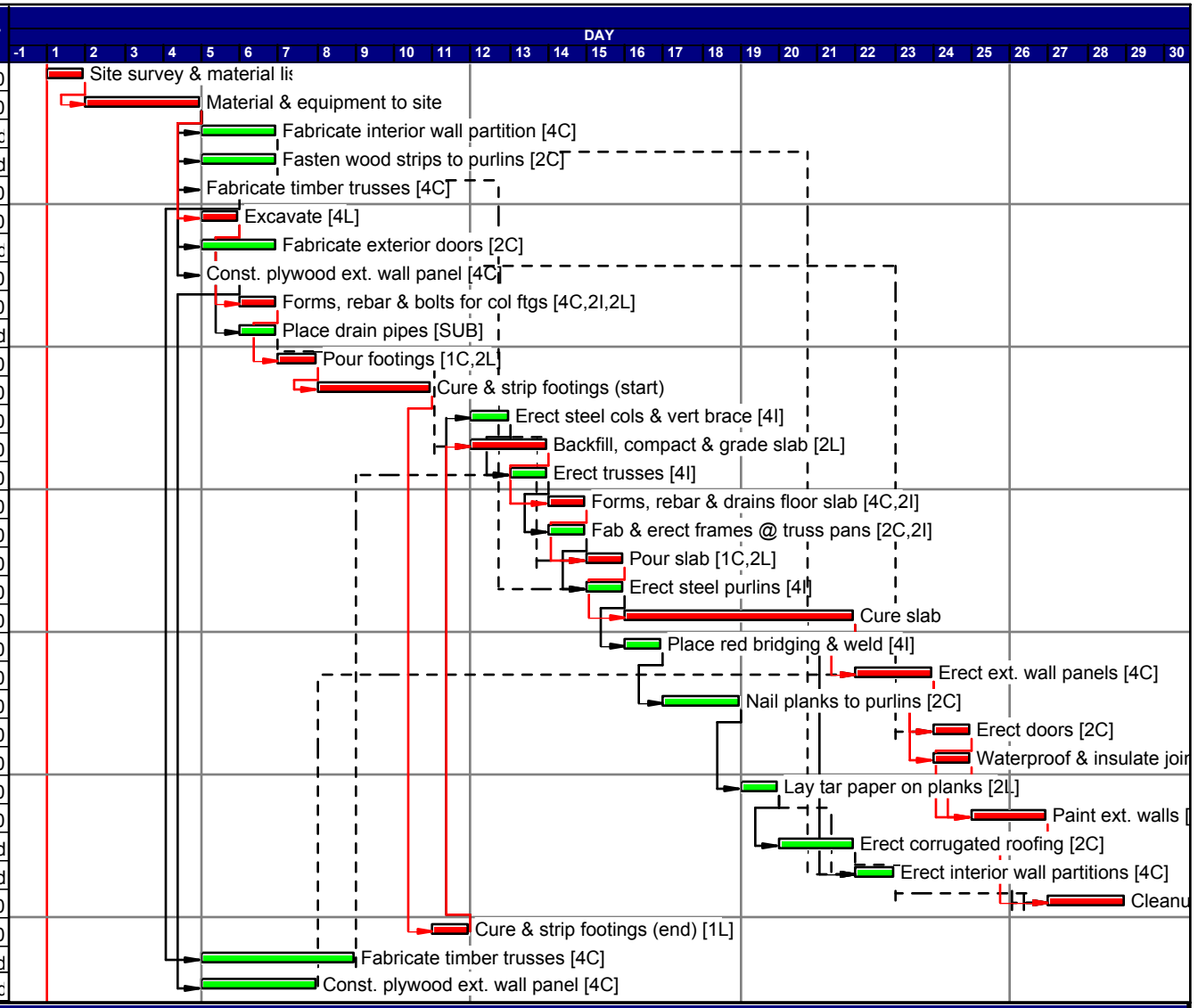
WARE Sheet 1 of 1

Warehouse Project (in P3)
28-day Orig. Schedule (Before Change Order)
Avail. Res.: 4Carpenters.,4Ironworkers, 4Laborers
Notice: Carpenters needed >> 4 Carp. available

C.O. changes Act. Durations (dT):
T3 = 2 + 6 = 8 (dT=6 < FF=15)
T7 = 2 + 5 = 7 (dT=5 < FF=17)
T8 = 3 + 9 = 12 (dT=9 < FF=14)
T29 = 1 + 3 = 4 (dT=3 < FF=4)

Because all Change Order
dT < Avail. FF,
the project owner refuses
to grant any time extension.

ID	Description	T	Pred	TF	FF
1	Site survey & material list	1		0	0
2	Material & equipment to site	3	1	0	0
3	Fabricate interior wall partition [4C]	2	2	19d	15c
4	Fasten wood strips to purlins [2C]	2	2	13d	8d
5	Fabricate timber trusses [4C]	0	2	9d	0
6	Excavate [4L]	1	2	0	0
7	Fabricate exterior doors [2C]	2	2	17d	17c
8	Const. plywood ext. wall panel [4C]	0	2	14d	0
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	6	0	0
10	Place drain pipes [SUB]	1	6	5d	5d
11	Pour footings [1C,2L]	1	9	0	0
12	Cure & strip footings (start)	3	11	0	0
13	Erect steel cols & vert brace [4I]	1	12B	2d	0
14	Backfill, compact & grade slab [2L]	2	10, 12B	0	0
15	Erect trusses [4I]	1	13, 5B	5d	0
16	Forms, rebar & drains floor slab [4C,2I]	1	14	0	0
17	Fab & erect frames @ truss pans [2C,2I]	1	15	5d	0
18	Pour slab [1C,2L]	1	13, 16	0	0
19	Erect steel purlins [4I]	1	17, 4	5d	0
20	Cure slab	6	18	0	0
21	Place red bridging & weld [4I]	1	19	5d	0
22	Erect ext. wall panels [4C]	2	20, 8B	0	0
23	Nail planks to purlins [2C]	2	21	5d	0
24	Erect doors [2C]	1	22, 7	0	0
25	Waterproof & insulate joints [2L]	1	22	0	0
26	Lay tar paper on planks [2L]	1	23	5d	0
27	Paint ext. walls [SUB]	2	24, 25	0	0
28	Erect corrugated roofing [2C]	2	26	5d	5d
29	Erect interior wall partitions [4C]	1	20, 26, 3	4d	4d
30	Cleanup [4L]	2	27, 28, 29	0	0
12E	Cure & strip footings (end) [1L]	1	12	0	0
5B	Fabricate timber trusses [4C	4	5	9d	4d
8B	Const. plywood ext. wall panel [4C]	3	8	14d	14c



ID	Description	Units	Display: Quantity
C	Carpenters	CA	16 20 9 4 6 1 2 2 2 2 8 4 2
I	Ironworkers	IW	2 4 4 4 4 4
L	Laborers	LB	4 2 2 1 2 2 2 2 4 4

-1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DAY

Start date	01JAN98
Finish date	28JAN98
Data date	01JAN98
Run date	19JUN03
Page number	1A
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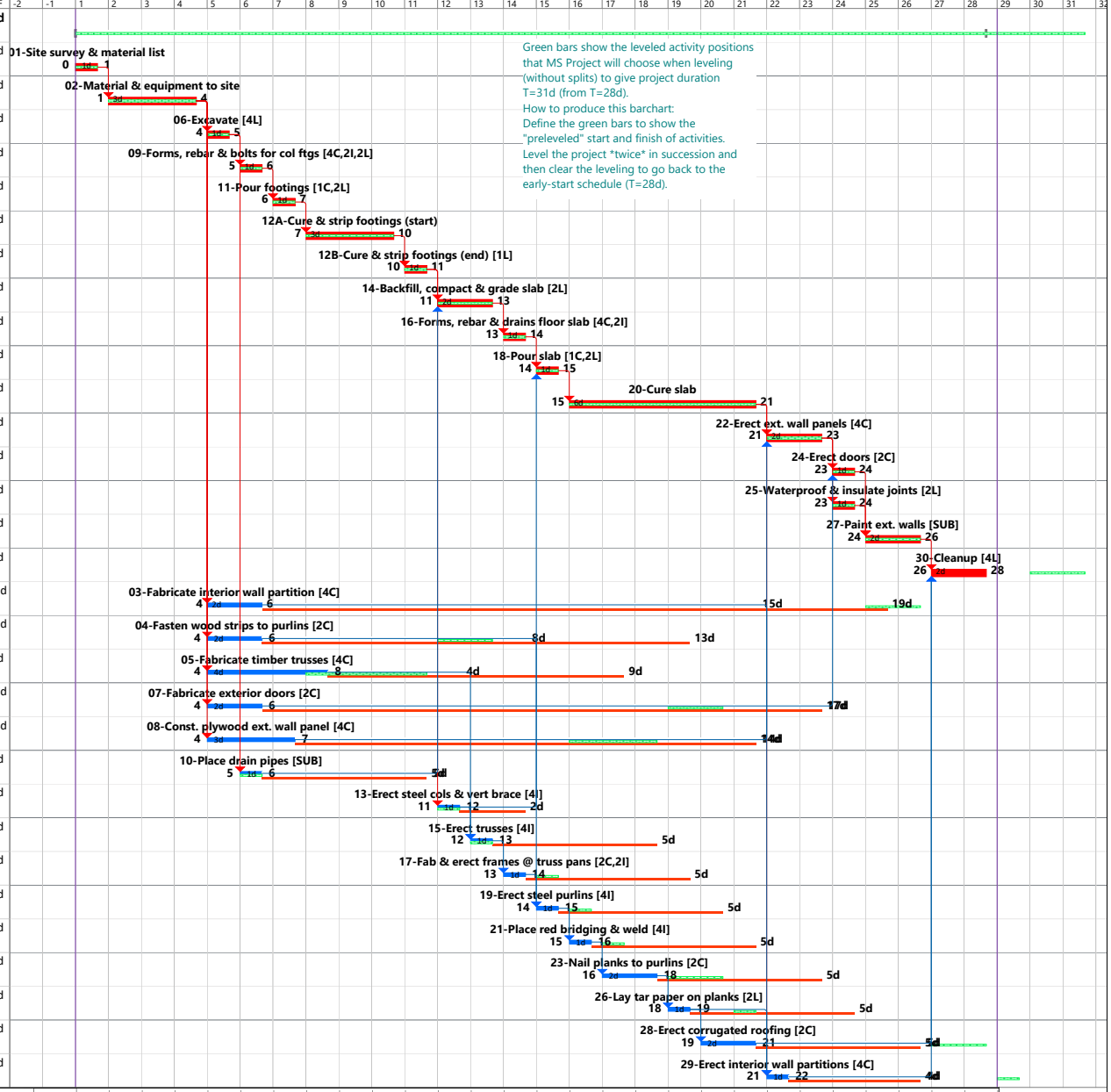
Warehouse Project (Before Change Order)
SureTrak, NoLeveling: T = 28 d
Avail. Res.: 4C,4I, 4L
Notice: Needed C >> 4

C.O. changes Act. Durations (dT):
T3 = 2 + 6 = 8 (dT=6 < FF=15)
T7 = 2 + 5 = 7 (dT=5 < FF=17)
T8 = 3 + 9 = 12 (dT=9 < FF=14)
T29 = 1 + 3 = 4 (dT=3 < FF=4)

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone poin

MS Project Pro | Project: Warehouse Project | Date: 11/12/21

ID	Act	Pred	T	Lev	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**28d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
6	06-Excavate [4L]	2	1d	0ed	4	4	4	5	5	5	0d	0d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	0ed	5	5	5	6	6	6	0d	0d
11	11-Pour footings [1C,2L]	9	1d	0ed	6	6	6	7	7	7	0d	0d
12	12A-Cure & strip footings (start)	11	3d	0ed	7	7	7	10	10	10	0d	0d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	10	10	10	11	11	11	0d	0d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	11	11	11	13	13	13	0d	0d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	13	13	13	14	14	14	0d	0d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	14	14	14	15	15	15	0d	0d
20	20-Cure slab	18	6d	0ed	15	15	15	21	21	21	0d	0d
22	22-Erect ext. wall panels [4C]	20,8	2d	0ed	21	21	21	23	23	23	0d	0d
24	24-Erect doors [2C]	7,22	1d	0ed	23	23	23	24	24	24	0d	0d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	23	23	23	24	24	24	0d	0d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	24	24	24	26	26	26	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	26	26	26	28	28	28	0d	0d
3	03-Fabricate interior wall partition [4C]	2	2d	0ed	4	4	23	6	6	25	15d	19d
4	04-Fasten wood strips to purlins [2C]	2	2d	0ed	4	4	17	6	6	19	8d	13d
5	05-Fabricate timber trusses [4C]	2	4d	0ed	4	4	13	8	8	17	4d	9d
7	07-Fabricate exterior doors [2C]	2	2d	0ed	4	4	21	6	6	23	17d	17d
8	08-Const. plywood ext. wall panel [4C]	2	3d	0ed	4	4	18	7	7	21	14d	14d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	10	6	6	11	5d	5d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	11	11	13	12	12	14	0d	2d
15	15-Erect trusses [4I]	13,5	1d	0ed	12	12	17	13	13	18	0d	5d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	0ed	13	13	18	14	14	19	0d	5d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	14	14	19	15	15	20	0d	5d
21	21-Place red bridging & weld [4I]	19	1d	0ed	15	15	20	16	16	21	0d	5d
23	23-Nail planks to purlins [2C]	21	2d	0ed	16	16	21	18	18	23	0d	5d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	18	18	23	19	19	24	0d	5d
28	28-Erect corrugated roofing [2C]	26	2d	0ed	19	19	24	21	21	26	5d	5d
29	29-Erect interior wall partitions [4C]	3,20,26	1d	0ed	21	21	25	22	22	26	4d	4d

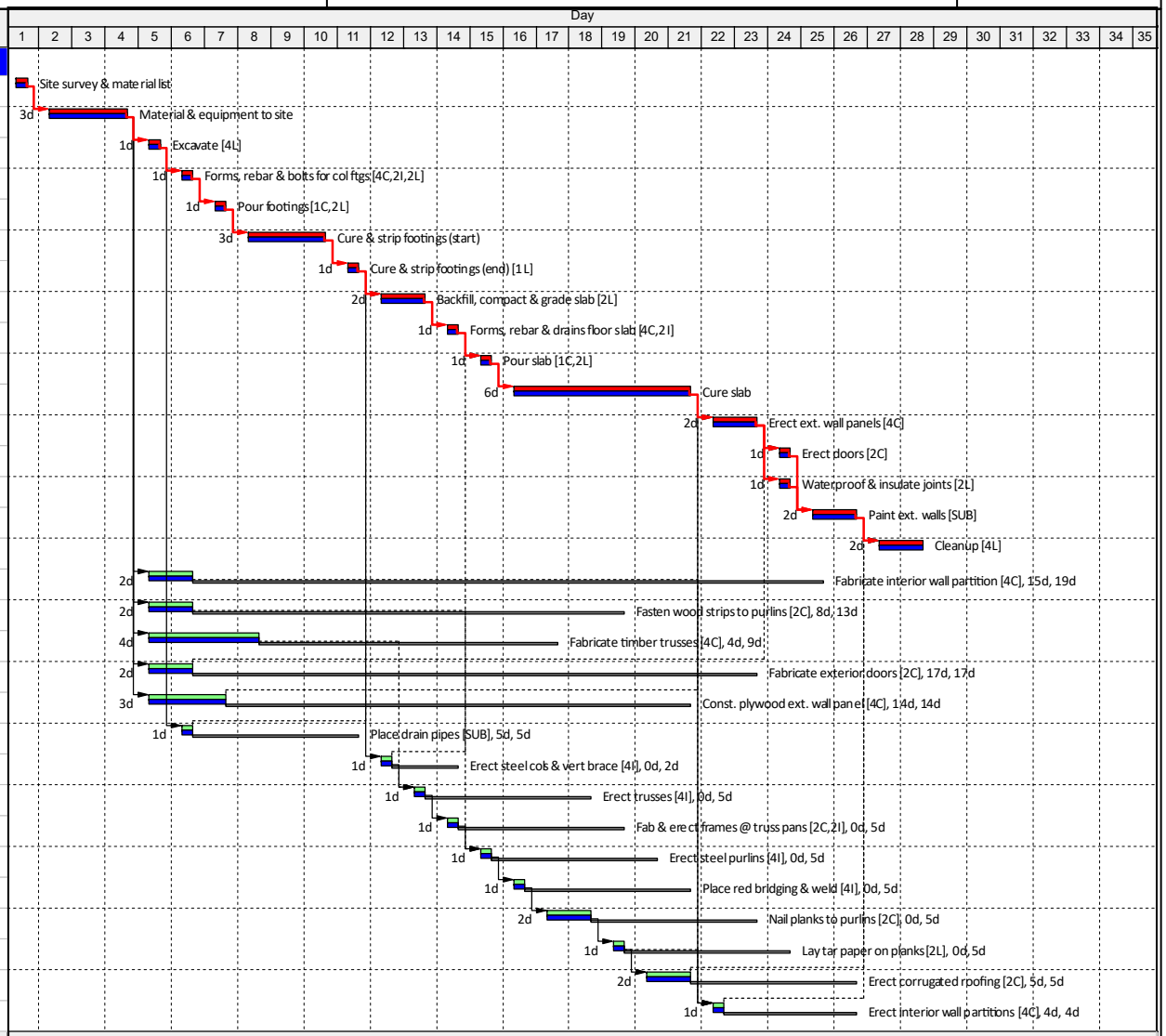


Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu". If you find this too difficult, you can print and submit the two reports separately.

ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	78d	Work
3	Laborers	27d	Work
2	Ironworkers	22d	Work

Primavera P6 Professional R20.12	Project: Warehouse-30+1 Acts-Unleveled-T=28d	Layout: 2021F-Lab6.1-Unleveled	Date: 30-11-21

ID	Act	Pred	Orig Dur	Start	Finish	FF	TF
Warehouse-30+1 Acts-Unleveled-T=28d			28d	01-11-21	28-11-21	0d	0d
01	Site survey & material list		1d	01-11-21	01-11-21	0d	0d
02	Material & equipment to site	01	3d	02-11-21	04-11-21	0d	0d
06	Excavate [4L]	02	1d	05-11-21	05-11-21	0d	0d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	06-11-21	06-11-21	0d	0d
11	Pour footings [1C,2L]	09	1d	07-11-21	07-11-21	0d	0d
12A	Cure & strip footings (start)	11	3d	08-11-21	10-11-21	0d	0d
12B	Cure & strip footings (end) [1L]	12A	1d	11-11-21	11-11-21	0d	0d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	12-11-21	13-11-21	0d	0d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	14-11-21	14-11-21	0d	0d
18	Pour slab [1C,2L]	13, 16	1d	15-11-21	15-11-21	0d	0d
20	Cure slab	18	6d	16-11-21	21-11-21	0d	0d
22	Erect ext. wall panels [4C]	20, 08	2d	22-11-21	23-11-21	0d	0d
24	Erect doors [2C]	07, 22	1d	24-11-21	24-11-21	0d	0d
25	Waterproof & insulate joints [2L]	22	1d	24-11-21	24-11-21	0d	0d
27	Paint ext. walls [SUB]	24, 25	2d	25-11-21	26-11-21	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	27-11-21	28-11-21	0d	0d
03	Fabricate interior wall partition [4C]	02	2d	05-11-21	06-11-21	15d	19d
04	Fasten wood strips to purlins [2C]	02	2d	05-11-21	06-11-21	8d	13d
05	Fabricate timber trusses [4C]	02	4d	05-11-21	08-11-21	4d	9d
07	Fabricate exterior doors [2C]	02	2d	05-11-21	06-11-21	17d	17d
08	Const. plywood ext. wall panel [4C]	02	3d	05-11-21	07-11-21	14d	14d
10	Place drain pipes [SUB]	06	1d	06-11-21	06-11-21	5d	5d
13	Erect steel cols & vert brace [4I]	12B	1d	12-11-21	12-11-21	0d	2d
15	Erect trusses [4I]	13, 05	1d	13-11-21	13-11-21	0d	5d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	14-11-21	14-11-21	0d	5d
19	Erect steel purlins [4I]	04, 17	1d	15-11-21	15-11-21	0d	5d
21	Place red bridging & weld [4I]	19	1d	16-11-21	16-11-21	0d	5d
23	Nail planks to purlins [2C]	21	2d	17-11-21	18-11-21	0d	5d
26	Lay tar paper on planks [2L]	23	1d	19-11-21	19-11-21	0d	5d
28	Erect corrugated roofing [2C]	26	2d	20-11-21	21-11-21	5d	5d
29	Erect interior wall partitions [4C]	03, 20, 26	1d	22-11-21	22-11-21	4d	4d



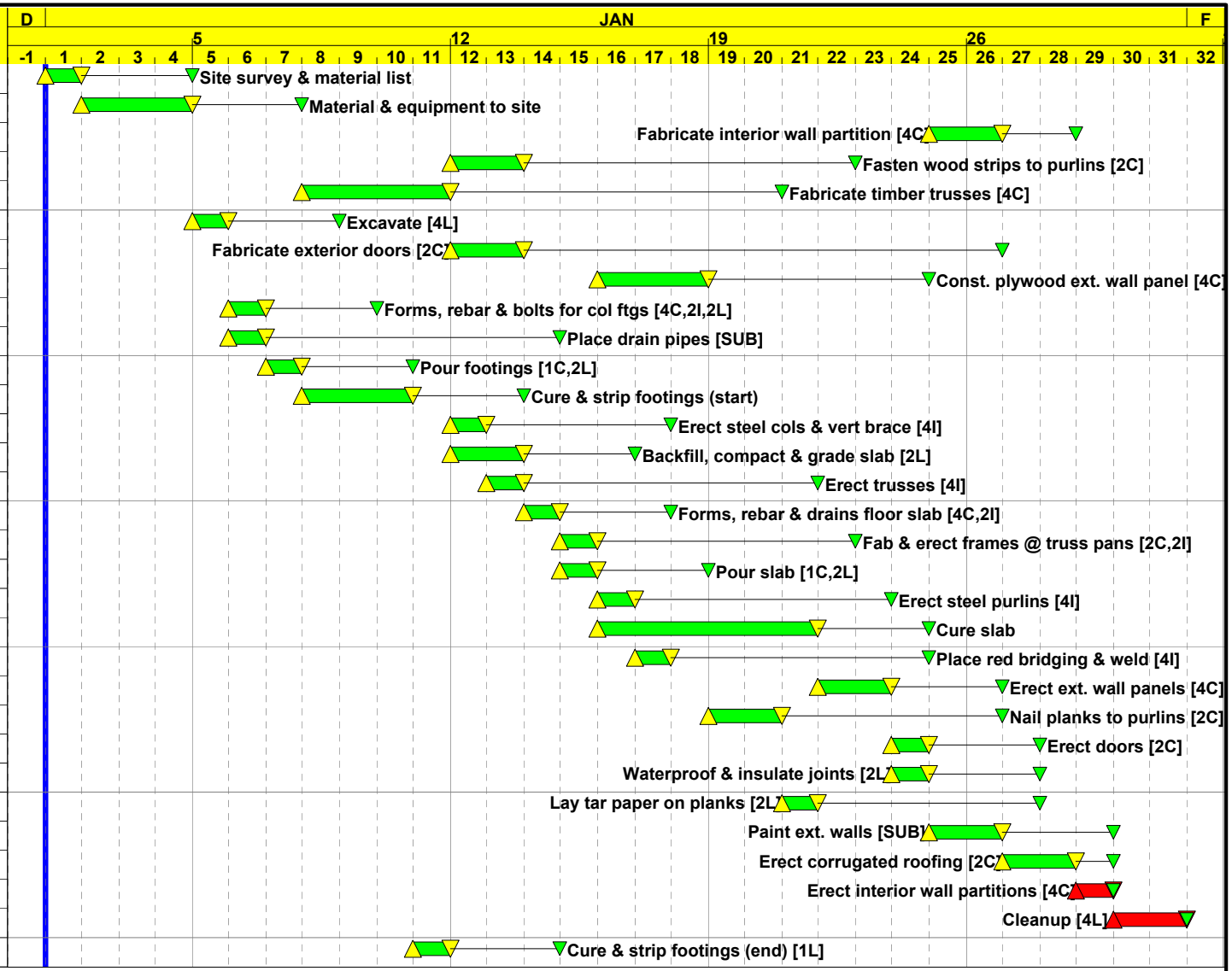
Activity ID	Activity Name	Start	Finish	Remaining Units	Day 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Total		05-11-21	28-11-21		20 24 11 4 1 6 6 10 7 4 2 2 2 2 2 8 4 4 4 4
Resource ID Name: C	Carpenter	05-11-21	24-11-21		16 20 9 4 6 1 2 2 2 2 8 4 2
Resource ID Name: I	Ironworkers	06-11-21	16-11-21		2 4 4 4 4 4
Resource ID Name: L	Laborers	05-11-21	28-11-21		4 2 2 1 2 2 2 2 4 4

Critical Rem Work
Remaining Work
Early Bar
Float Bar

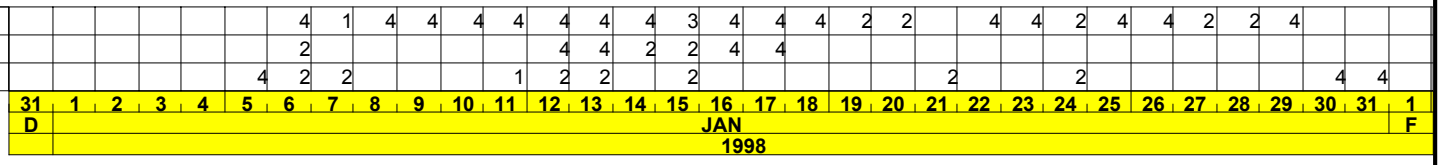
Date	Revision	Check...	Approved
11-14-21	Early-Start Schedule, Unleveled, T=28d	PGI	PGI
	(To print all 3 res rows in sprdsht, select them on screen)		
	Sorted by: Critical, Early Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

ID	Act	T	TF	FF
1	Site survey & material list	1	3	0
2	Material & equipment to site	3	3	0
3	Fabricate interior wall partition [4C]	2	2	2
4	Fasten wood strips to purlins [2C]	2	9	2
5	Fabricate timber trusses [4C]	4	9	1
6	Excavate [4L]	1	3	0
7	Fabricate exterior doors [2C]	2	13	10
8	Const. plywood ext. wall panel [4C]	3	6	3
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	3	0
10	Place drain pipes [SUB]	1	8	5
11	Pour footings [1C,2L]	1	3	0
12	Cure & strip footings (start)	3	3	0
13	Erect steel cols & vert brace [4I]	1	5	0
14	Backfill, compact & grade slab [2L]	2	3	0
15	Erect trusses [4I]	1	8	1
16	Forms, rebar & drains floor slab [4C,2I]	1	3	0
17	Fab & erect frames @ truss pans [2C,2I]	1	7	0
18	Pour slab [1C,2L]	1	3	0
19	Erect steel purlins [4I]	1	7	0
20	Cure slab	6	3	0
21	Place red bridging & weld [4I]	1	7	1
22	Erect ext. wall panels [4C]	2	3	0
23	Nail planks to purlins [2C]	2	6	0
24	Erect doors [2C]	1	3	0
25	Waterproof & insulate joints [2L]	1	3	0
26	Lay tar paper on planks [2L]	1	6	5
27	Paint ext. walls [SUB]	2	3	3
28	Erect corrugated roofing [2C]	2	1	1
29	Erect interior wall partitions [4C]	1	0	0
30	Cleanup [4L]	2	0	0
12B	Cure & strip footings (end) [1L]	1	3	0



Row	Group Name
1	Carpenters
2	Ironworkers
3	Laborers



Start Date 01JAN98
Finish Date 31JAN98
Data Date 01JAN98
Run Date 19JUN03 15:18

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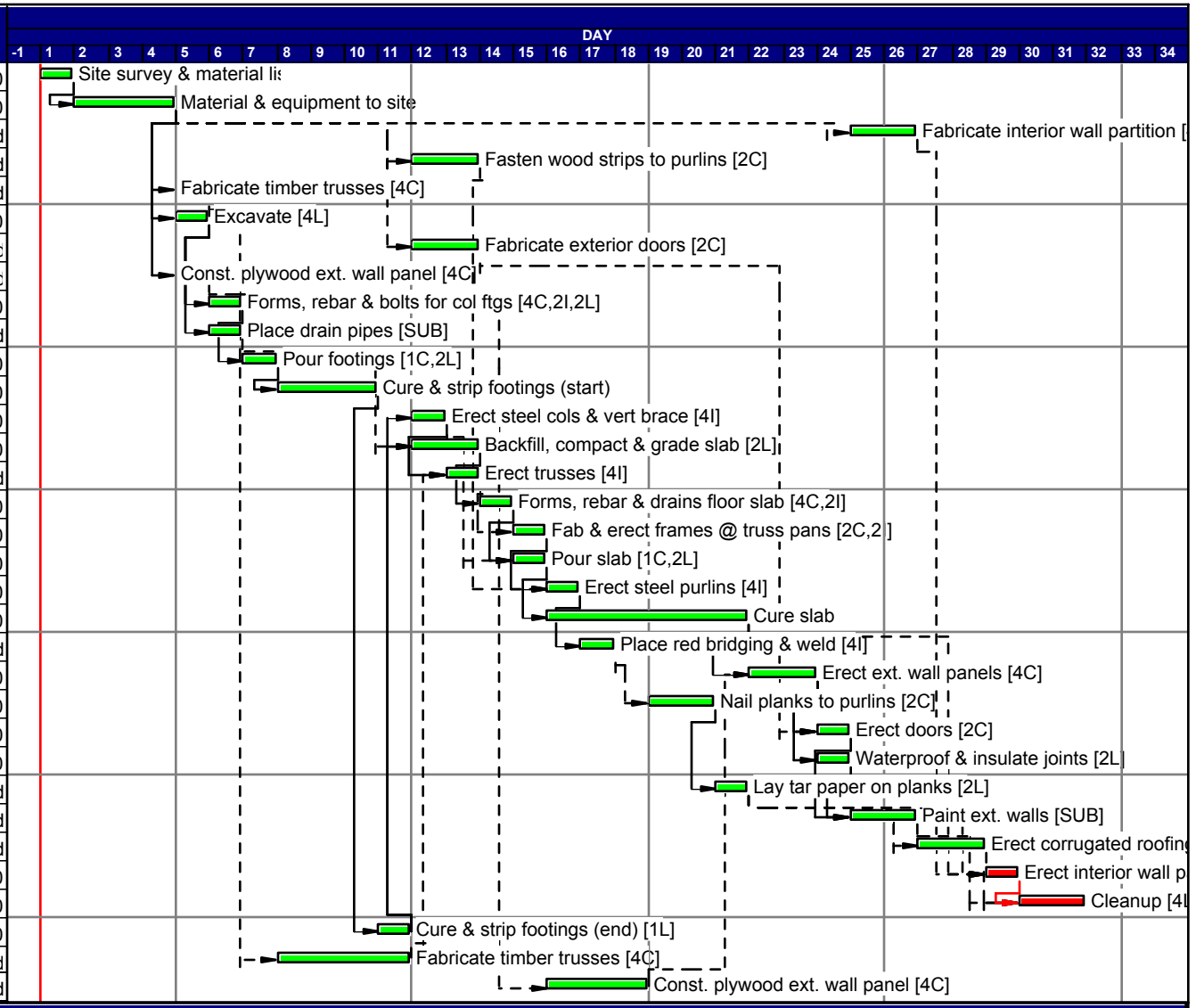
Early Bar
Float Bar
Progress Bar
Critical Activity

WARE Sheet 1 of 1

Warehouse Project
Original Activity Durations
Leveled by P3, No Splits: T=31 days

Fondahl found the same result using P3 and no splits

ID	Description	T	Pred	TF	FF
1	Site survey & material list	1		3d	0
2	Material & equipment to site	3	1	3d	0
3	Fabricate interior wall partition [4C]	2	2	2d	2d
4	Fasten wood strips to purlins [2C]	2	2	9d	2d
5	Fabricate timber trusses [4C]	0	2	12d	3d
6	Excavate [4L]	1	2	3d	0
7	Fabricate exterior doors [2C]	2	2	13d	10c
8	Const. plywood ext. wall panel [4C]	0	2	17d	11c
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	6	3d	0
10	Place drain pipes [SUB]	1	6	8d	5d
11	Pour footings [1C,2L]	1	9	3d	0
12	Cure & strip footings (start)	3	11	3d	0
13	Erect steel cols & vert brace [4I]	1	12B	5d	0
14	Backfill, compact & grade slab [2L]	2	10, 12B	3d	0
15	Erect trusses [4I]	1	13, 5B	8d	1d
16	Forms, rebar & drains floor slab [4C,2I]	1	14	3d	0
17	Fab & erect frames @ truss pans [2C,2I]	1	15	7d	0
18	Pour slab [1C,2L]	1	13, 16	3d	0
19	Erect steel purlins [4I]	1	17, 4	7d	0
20	Cure slab	6	18	3d	0
21	Place red bridging & weld [4I]	1	19	7d	1d
22	Erect ext. wall panels [4C]	2	20, 8B	3d	0
23	Nail planks to purlins [2C]	2	21	6d	0
24	Erect doors [2C]	1	22, 7	3d	0
25	Waterproof & insulate joints [2L]	1	22	3d	0
26	Lay tar paper on planks [2L]	1	23	6d	5d
27	Paint ext. walls [SUB]	2	24, 25	3d	3d
28	Erect corrugated roofing [2C]	2	26	1d	1d
29	Erect interior wall partitions [4C]	1	20, 26, 3	0	0
30	Cleanup [4L]	2	27, 28, 29	0	0
12E	Cure & strip footings (end) [1L]	1	12	3d	0
5B	Fabricate timber trusses [4C	4	5	9d	1d
8B	Const. plywood ext. wall panel [4C]	3	8	6d	3d



ID	Description	Units	Total	Display: Quantity
C	Carpenters	CA	78	4 1 4 4 4 4 4 4 4 3 4 4 4 2 2 4 4 2 4 4 2 2 4
I	Ironworkers	IW	22	2 4 4 2 2 4 4
L	Laborers	LB	27	4 2 2 1 2 2 2 2 2 4 4
Total				0 0 0 0 0 4 8 3 4 4 4 5 * * 6 7 8 8 4 2 2 2 4 4 4 4 4 2 2 4 4 4 0 0 0

Start date	01JAN98
Finish date	31JAN98
Data date	01JAN98
Run date	19JUN03
Page number	1A
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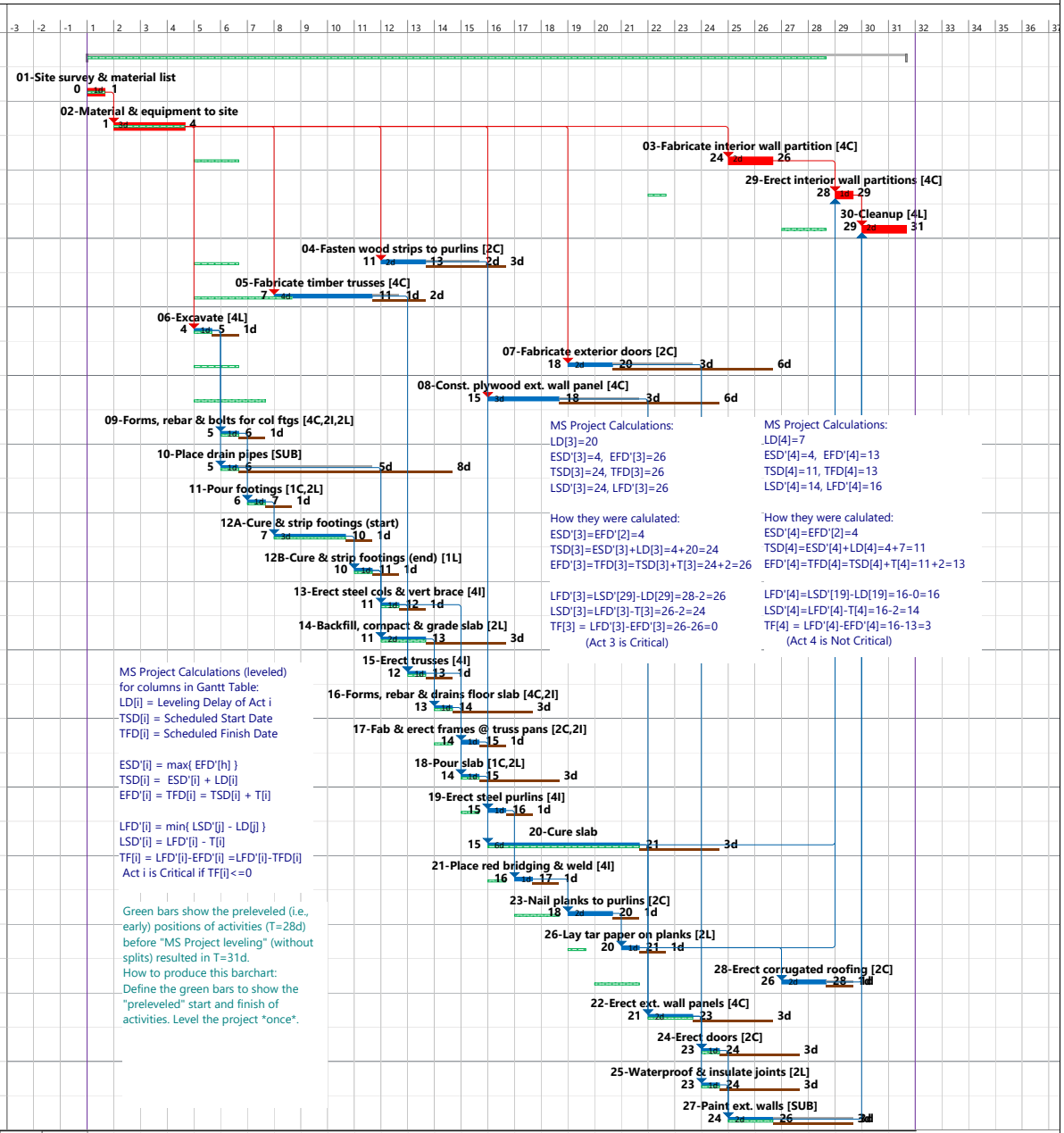
Warehouse Project (Before Change Order)
Levelled by SureTrak, No Splits: T = 31 days
(No Splits: T5=0, T5B=4, T8 = 0, T8B= 3)

Same as P3 and Fondahl without splitting

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone poin

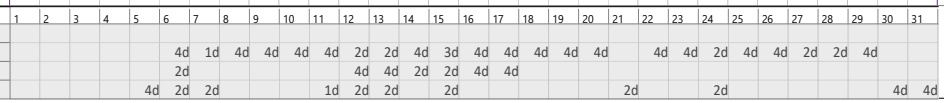
MS Project Pro | Project: Warehouse Project | Date: 11/14/21

ID	Act	Pred	T	Lev Del	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**31d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
3	03-Fabricate interior wall partition [4C]	2	2d	20ed	4	24	24	26	26	26	0d	0d
29	29-Erect interior wall partitions [4C]	3,20,26	1d	2ed	26	28	28	29	29	29	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	29	29	29	31	31	31	0d	0d
4	04-Fasten wood strips to purlins [2C]	2	2d	7ed	4	11	14	13	13	16	2d	3d
5	05-Fabricate timber trusses [4C]	2	4d	3ed	4	7	9	11	11	13	1d	2d
6	06-Excavate [4L]	2	1d	0ed	4	4	5	5	5	6	0d	1d
7	07-Fabricate exterior doors [2C]	2	2d	14ed	4	18	24	20	20	26	3d	6d
8	08-Const. plywood ext. wall panel [4C]	2	3d	11ed	4	15	21	18	18	24	3d	6d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	0ed	5	5	6	6	6	7	0d	1d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	13	6	6	14	5d	8d
11	11-Pour footings [1C,2L]	9	1d	0ed	6	6	7	7	7	8	0d	1d
12	12A-Cure & strip footings (start)	11	3d	0ed	7	7	8	10	10	11	0d	1d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	10	10	11	11	11	12	0d	1d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	11	11	12	12	12	13	0d	1d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	11	11	14	13	13	16	0d	3d
15	15-Erect trusses [4I]	13,5	1d	0ed	12	12	13	13	13	14	0d	1d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	13	13	16	14	14	17	0d	3d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	1ed	13	14	15	15	15	16	0d	1d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	14	14	17	15	15	18	0d	3d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	15	15	16	16	16	17	0d	1d
20	20-Cure slab	18	6d	0ed	15	15	18	21	21	24	0d	3d
21	21-Place red bridging & weld [4I]	19	1d	0ed	16	16	17	17	17	18	0d	1d
23	23-Nail planks to purlins [2C]	21	2d	1ed	17	18	19	20	20	21	0d	1d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	20	20	21	21	21	22	0d	1d
28	28-Erect corrugated roofing [2C]	26	2d	5ed	21	26	27	28	28	29	1d	1d
22	22-Erect ext. wall panels [4C]	20,8	2d	0ed	21	21	24	23	23	26	0d	3d
24	24-Erect doors [2C]	7,22	1d	0ed	23	23	26	24	24	27	0d	3d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	23	23	26	24	24	27	0d	3d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	24	24	27	26	26	29	3d	3d



Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu".
If you find this too difficult, you can print and submit the two reports separately.

ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	78d	Work
2	Ironworkers	22d	Work
3	Laborers	27d	Work



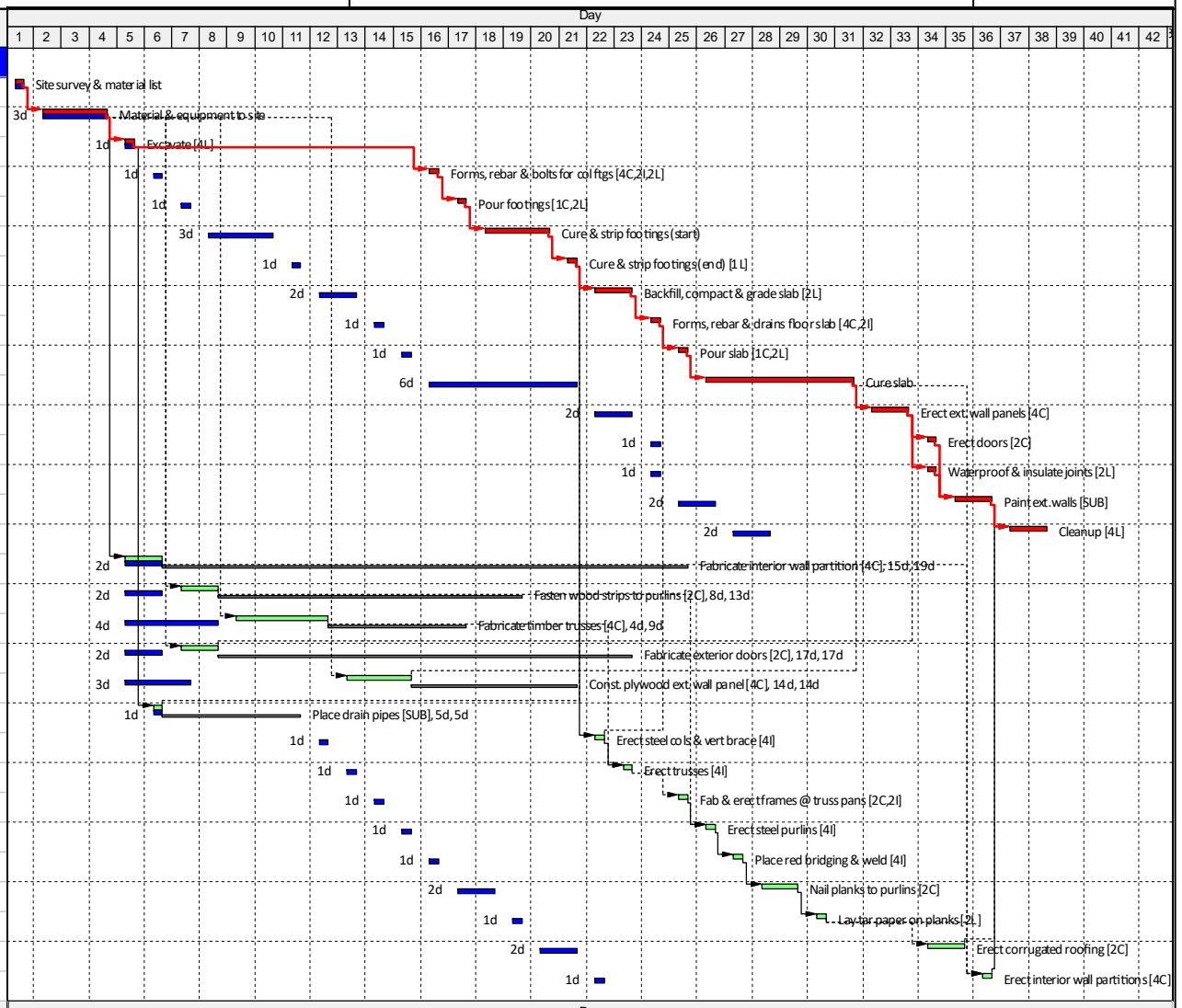
_Lab6 Gantt Chart - No Splits
Sorted by: Critical, Preleveled Start, Name

Leveled by MS Project without splitting activities - Project duration T=31d (same as P3)

Course: CEE538
User: P.G. Ioannou

Primavera P6 Professional R20.12	Project: Warehouse-No Splits-Default-Leveling-T=38d	Layout: 2021F-Lab6.2-Default Leveling-No Splits	Date: 08-12-21

ID	Act	Pred	Orig Dur	Start	Finish	FF	TF
Warehouse-No Splits-Default-Leveling-T:			38d	01-11-21	08-12-21	0d	0d
01	Site survey & material list		1d	01-11-21	01-11-21	0d	0d
02	Material & equipment to site	01	3d	02-11-21	04-11-21	0d	0d
06	Excavate [4L]	02	1d	05-11-21	05-11-21	0d	0d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	16-11-21	16-11-21	0d	0d
11	Pour footings [1C,2L]	09	1d	17-11-21	17-11-21	0d	0d
12A	Cure & strip footings (start)	11	3d	18-11-21	20-11-21	0d	0d
12B	Cure & strip footings (end) [1L]	12A	1d	21-11-21	21-11-21	0d	0d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	22-11-21	23-11-21	0d	0d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	24-11-21	24-11-21	0d	0d
18	Pour slab [1C,2L]	13, 16	1d	25-11-21	25-11-21	0d	0d
20	Cure slab	18	6d	26-11-21	01-12-21	0d	0d
22	Erect ext. wall panels [4C]	20, 08	2d	02-12-21	03-12-21	0d	0d
24	Erect doors [2C]	07, 22	1d	04-12-21	04-12-21	0d	0d
25	Waterproof & insulate joints [2L]	22	1d	04-12-21	04-12-21	0d	0d
27	Paint ext. walls [SUB]	24, 25	2d	05-12-21	06-12-21	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	07-12-21	08-12-21	0d	0d
03	Fabricate interior wall partition [4C]	02	2d	05-11-21	06-11-21	15d	19d
04	Fasten wood strips to purlins [2C]	02	2d	07-11-21	08-11-21	8d	13d
05	Fabricate timber trusses [4C]	02	4d	09-11-21	12-11-21	4d	9d
07	Fabricate exterior doors [2C]	02	2d	07-11-21	08-11-21	17d	17d
08	Const. plywood ext. wall panel [4C]	02	3d	13-11-21	15-11-21	14d	14d
10	Place drain pipes [SUB]	06	1d	06-11-21	06-11-21	5d	5d
13	Erect steel cols & vert brace [4I]	12B	1d	22-11-21	22-11-21	0d	2d
15	Erect trusses [4I]	13, 05	1d	23-11-21	23-11-21	0d	5d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	25-11-21	25-11-21	0d	5d
19	Erect steel purlins [4I]	04, 17	1d	26-11-21	26-11-21	0d	5d
21	Place red bridging & weld [4I]	19	1d	27-11-21	27-11-21	0d	5d
23	Nail planks to purlins [2C]	21	2d	28-11-21	29-11-21	0d	5d
26	Lay tar paper on planks [2L]	23	1d	30-11-21	30-11-21	0d	5d
28	Erect corrugated roofing [2C]	26	2d	04-12-21	05-12-21	5d	5d
29	Erect interior wall partitions [4C]	03, 20, 26	1d	06-12-21	06-12-21	4d	4d



Activity ID	Activity Name	Start	Finish	Remaining Units
Total		05-11-21	08-12-21	
Resource ID Name: C	Carpenters	05-11-21	06-12-21	
Resource ID Name: I	Ironworkers	16-11-21	27-11-21	
Resource ID Name: L	Laborers	05-11-21	08-12-21	

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Total					8	4	4	4	4	4	4	4	4	4	4	8	3				1	6	6	6	7	4	4	2	2	2		4	4	6	2	4	4	4					
Resource ID Name: C					4	4	4	4	4	4	4	4	4	4	4	4	1							4	3			2	2			4	4	4	2	4							
Resource ID Name: I																2						4	4	2	2	4	4																
Resource ID Name: L					4											2	2				1	2	2		2					2				2			4	4					

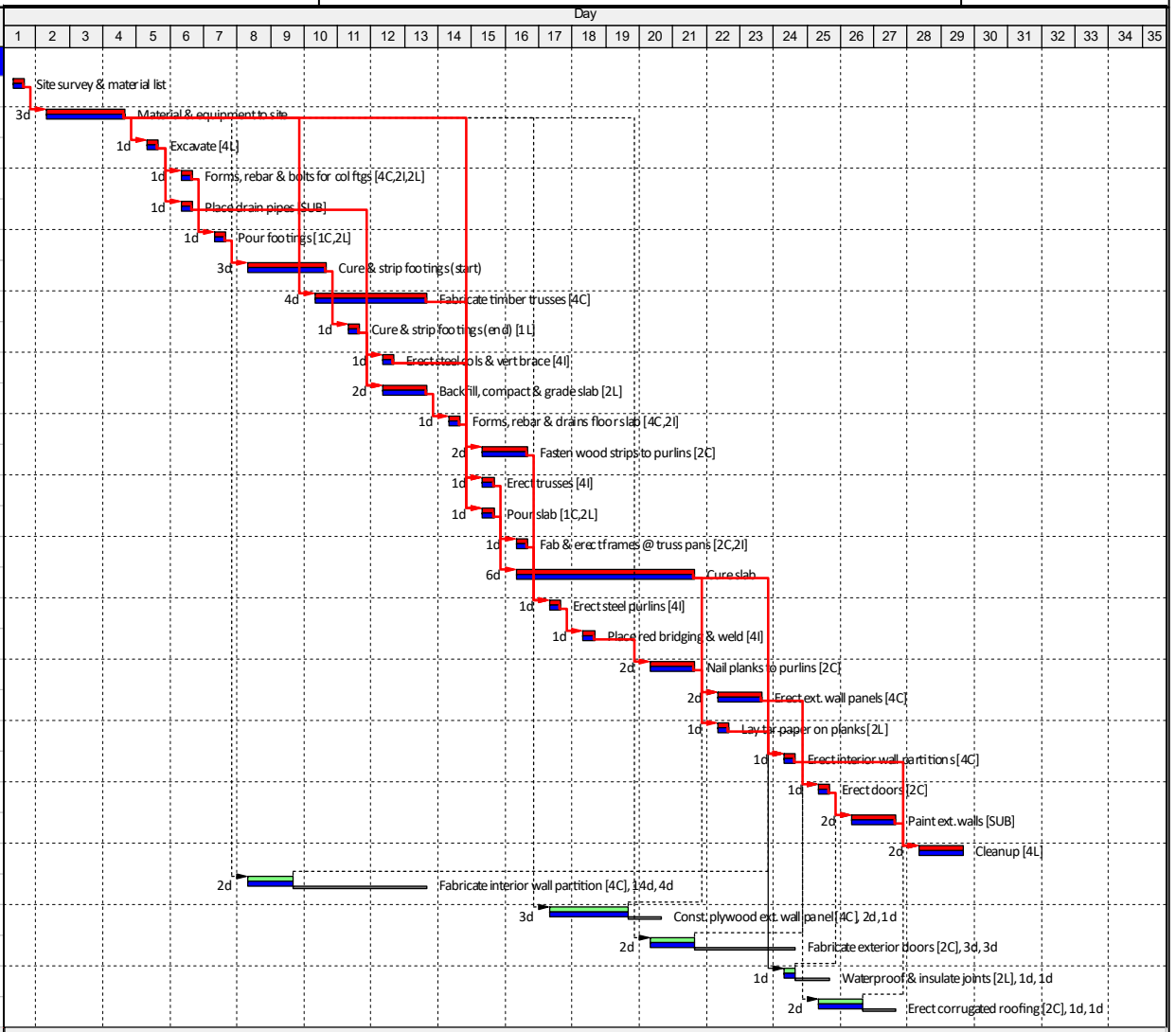
Critical Rem Work
Remaining Work
Early Bar
Float Bar

Date	Revision	Checked	Approved
8-12-21	Default leveling by P6, No splits, T=38d	PGI	PGI
	Preserve schedule early and late dates: YES		
	Sorted by: Critical, Early Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

Primavera P6 Professional R20.12	Project: Warehouse-No Splits-TF-Leveling-T=29d	Layout: 2021F-Lab6.2-TF Leveling-No Splits	Date: 14-11-21

ID	Act	Pred	Orig Dur	Start	Finish	FF	TF
Warehouse-No Splits-TF-Leveling-T=29d			29d	01-11-21	29-11-21	0d	0d
01	Site survey & material list		1d	01-11-21	01-11-21	0d	-9d
02	Material & equipment to site	01	3d	02-11-21	04-11-21	0d	-9d
06	Excavate [4L]	02	1d	05-11-21	05-11-21	0d	-9d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	06-11-21	06-11-21	0d	-9d
10	Place drain pipes [SUB]	06	1d	06-11-21	06-11-21	5d	-4d
11	Pour footings [1C,2L]	09	1d	07-11-21	07-11-21	0d	-9d
12A	Cure & strip footings (start)	11	3d	08-11-21	10-11-21	0d	-9d
05	Fabricate timber trusses [4C]	02	4d	10-11-21	13-11-21	1d	-4d
12B	Cure & strip footings (end) [1L]	12A	1d	11-11-21	11-11-21	0d	-9d
13	Erect steel cols & vert brace [4I]	12B	1d	12-11-21	12-11-21	2d	-3d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	12-11-21	13-11-21	0d	-9d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	14-11-21	14-11-21	0d	-9d
04	Fasten wood strips to purlins [2C]	02	2d	15-11-21	16-11-21	0d	-5d
15	Erect trusses [4I]	13, 05	1d	15-11-21	15-11-21	0d	-5d
18	Pour slab [1C,2L]	13, 16	1d	15-11-21	15-11-21	0d	-5d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	16-11-21	16-11-21	0d	-5d
20	Cure slab	18	6d	16-11-21	21-11-21	0d	-5d
19	Erect steel purlins [4I]	04, 17	1d	17-11-21	17-11-21	0d	-5d
21	Place red bridging & weld [4I]	19	1d	18-11-21	18-11-21	1d	-5d
23	Nail planks to purlins [2C]	21	2d	20-11-21	21-11-21	0d	-6d
22	Erect ext. wall panels [4C]	20, 08	2d	22-11-21	23-11-21	0d	-1d
26	Lay tar paper on planks [2L]	23	1d	22-11-21	22-11-21	1d	-6d
29	Erect interior wall partitions [4C]	03, 20, 26	1d	24-11-21	24-11-21	3d	-7d
24	Erect doors [2C]	07, 22	1d	25-11-21	25-11-21	0d	0d
27	Paint ext. walls [SUB]	24, 25	2d	26-11-21	27-11-21	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	28-11-21	29-11-21	0d	0d
03	Fabricate interior wall partition [4C]	02	2d	08-11-21	09-11-21	14d	4d
08	Const. plywood ext. wall panel [4C]	02	3d	17-11-21	19-11-21	2d	1d
07	Fabricate exterior doors [2C]	02	2d	20-11-21	21-11-21	3d	3d
25	Waterproof & insulate joints [2L]	22	1d	24-11-21	24-11-21	1d	1d
28	Erect corrugated roofing [2C]	26	2d	25-11-21	26-11-21	1d	1d



Activity ID	Activity Name	Start	Finish	Remaining Units	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Total		05-11-21	29-11-21						4	8	3	4	4	4	5	10	6	6	9	6	8	8	4	4	4	6	4	6	4	2		4	4							
Resource ID Name: WARE - Root		05-11-21	29-11-21						4	8	3	4	4	4	5	10	6	6	9	6	8	8	4	4	4	6	4	6	4	2		4	4							
Resource ID Name: C Carpenter		06-11-21	26-11-21							4	1	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	2										
Resource ID Name: I Ironworkers		06-11-21	18-11-21							2						4		2	4	2	4	4																	
Resource ID Name: L Laborers		05-11-21	29-11-21						4	2	2				1	2	2		2							2		2				4	4						

Critical Rem Work
Float Bar
Remaining Work
Early Bar

Date	Revision	Checked	Approved
14-11-21	Repeated TF-leveling by P6, No splits, T=29d	PGI	PGI
	Preserve schedule early and late dates: No		
	Sorted by: Critical, Early Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

TABLE 2. Resource Leveling Effects on Criticality–Warehouse Project[1]

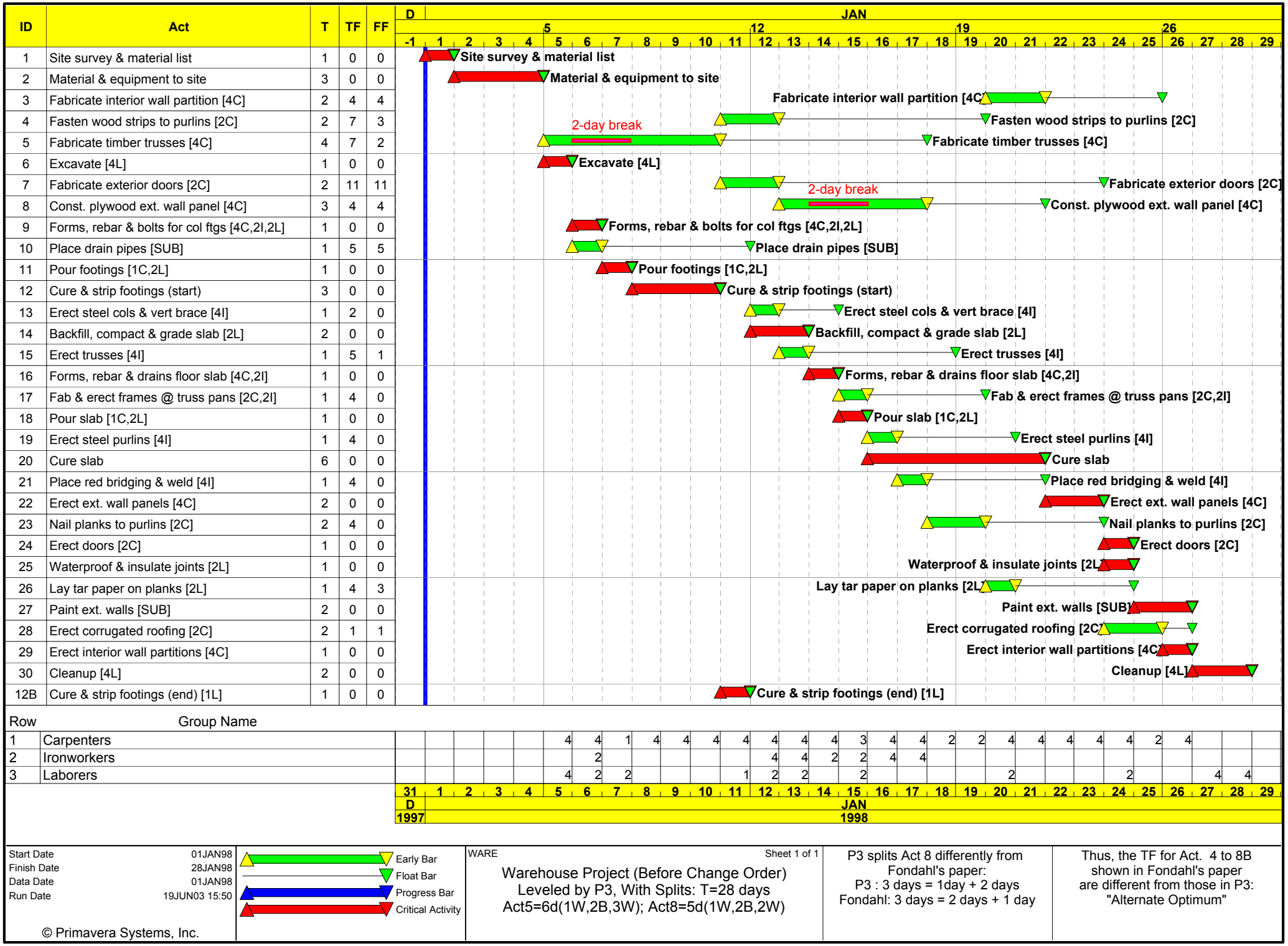
MSP Act ID (1)	P6 Act ID (1)	Total float before leveling (2)	Original critical (3)	Total float used in rescheduling (4)	Theoretical remaining total float (5)	Actual remaining total float (6)	Critical after leveling (7)
1	1	0	C	-	-	-	C
2	2	0	C	-	-	-	C
3	3	19	-	15	4	0	C
4	4	13	-	2	11	0	C
5 (1d)	5A (1d)	9	-	0	9	0	C
32 (3d)	5B (3d)	9	-	3	6	0	C
6	6	0	C	-	-	-	C
7	7	17	-	12	5	1	-
8 (1d)	8A (1d)	14	-	7	7	0	C
33 (2d)	8B (2d)	14	-	9	5	1	-
9	9	0	C	-	-	-	C
10	10	5	-	0	5	5	-
11	11	0	C	-	-	-	C
12 (3d)	12A (3d)	0	C	-	-	-	C
31 (1d)	12B (1d)	0	C	-	-	-	C
13	13	2	-	0	2	0	C
14	14	0	C	-	-	-	C
15	15	5	-	0	5	0	C
16	16	0	C	-	-	-	C
17	17	5	-	1	4	0	C
18	18	0	C	-	-	-	C
19	19	5	-	1	4	0	C
20	20	0	C	-	-	-	C
21	21	5	-	1	4	0	C
22	22	0	C	-	-	-	C
23	23	5	-	1	4	0	C
24	24	0	C	-	-	-	C
25	25	0	C	-	-	-	C
26	26	5	-	1	4	3	-
27	27	0	C	-	-	-	C
28	28	5	-	4	1	0	C
29	29	4	-	4	0	0	C
30	30	0	C	-	-	-	C

[1] Table 2 is a revised version of Table 1 from the paper:
Fondahl, J. (1991). "*The Development of the Construction Engineer: Past Progress and Future Problems*" J. Constr. Eng. Mgmt., ASCE, Vol 117, No 3, pp 380-392.

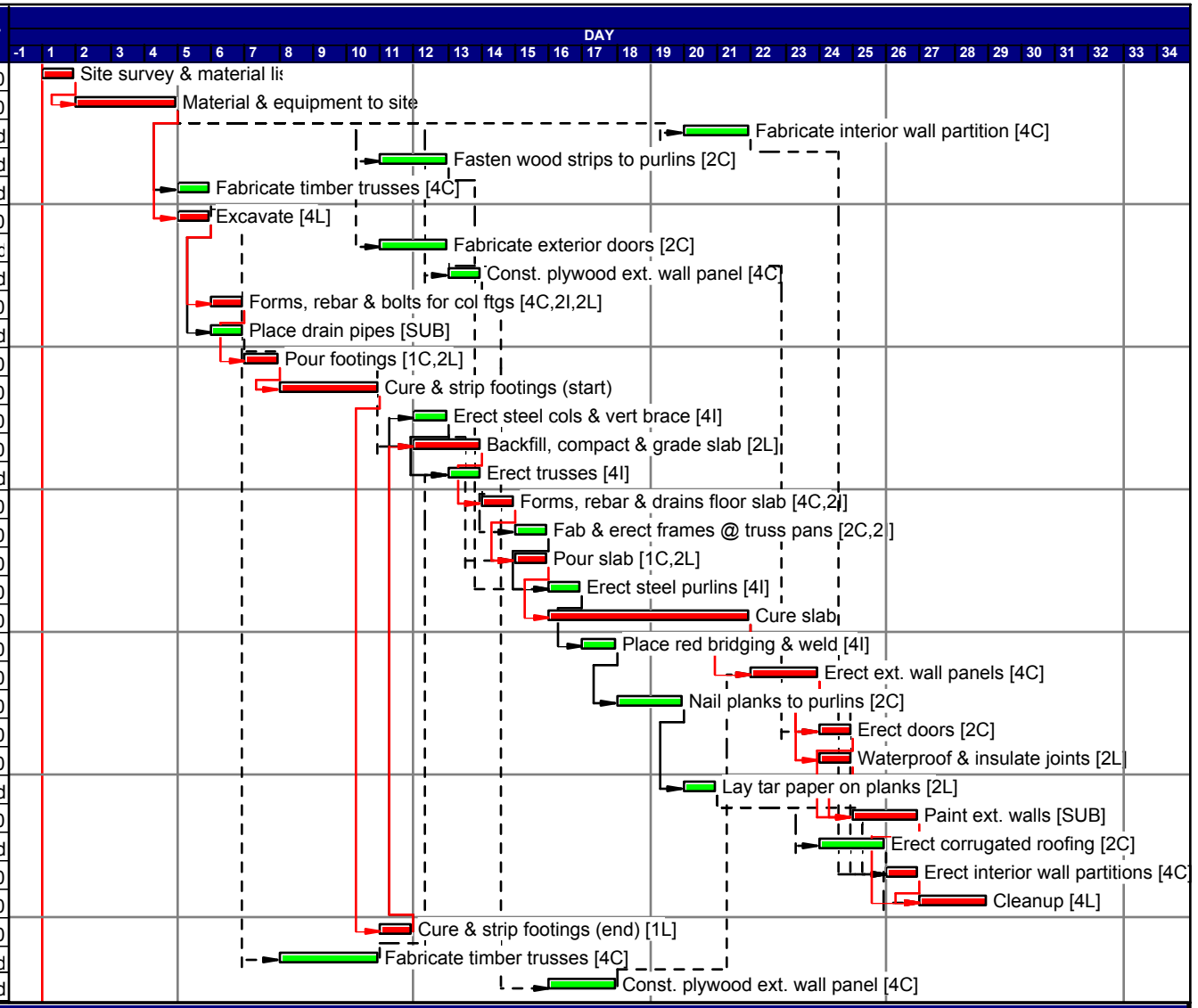
Main changes: In Table 2, each of the three activities 5, 8, and 12 has been split into two activities as follows:

Original Activity (Dur)		**Split MS Project Activities** (Dur)	**Split P6 Activities** (Dur)
5 (4d)	=	**5** (1d) + **32** (3d)	**5A** (1d) + **5B** (3d)
8 (3d)	=	**8** (1d) + **33** (2d)	**8A** (1d) + **8B** (2d)
12 (4d)	=	**12** (3d) + **31** (1d)	**12A** (3d) + **12B** (1d)

This enables MS Project and P6 (neither of which can split activities automatically when leveling resources) to "split" into two activities each of the three activities 5, 8, and 12, as described by Fondahl (1991).


ID
Act
T
TF
FF
D
JAN
-1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
5
12
19
26
1 Site survey & material list 1 0 0
2 Material & equipment to site 3 0 0
3 Fabricate interior wall partition [4C] 2 4 4
4 Fasten wood strips to purlins [2C] 2 7 3
5 Fabricate timber trusses [4C] 4 7 2
6 Excavate [4L] 1 0 0
7 Fabricate exterior doors [2C] 2 11 11
8 Const. plywood ext. wall panel [4C] 3 4 4
9 Forms, rebar & bolts for col ftgs [4C,2I,2L] 1 0 0
10 Place drain pipes [SUB] 1 5 5
11 Pour footings [1C,2L] 1 0 0
12 Cure & strip footings (start) 3 0 0
13 Erect steel cols & vert brace [4I] 1 2 0
14 Backfill, compact & grade slab [2L] 2 0 0
15 Erect trusses [4I] 1 5 1
16 Forms, rebar & drains floor slab [4C,2I] 1 0 0
17 Fab & erect frames @ truss pans [2C,2I] 1 4 0
18 Pour slab [1C,2L] 1 0 0
19 Erect steel purlins [4I] 1 4 0
20 Cure slab 6 0 0
21 Place red bridging & weld [4I] 1 4 0
22 Erect ext. wall panels [4C] 2 0 0
23 Nail planks to purlins [2C] 2 4 0
24 Erect doors [2C] 1 0 0
25 Waterproof & insulate joints [2L] 1 0 0
26 Lay tar paper on planks [2L] 1 4 3
27 Paint ext. walls [SUB] 2 0 0
28 Erect corrugated roofing [2C] 2 1 1
29 Erect interior wall partitions [4C] 1 0 0
30 Cleanup [4L] 2 0 0
12B Cure & strip footings (end) [1L] 1 0 0
Site survey & material list
Material & equipment to site
Fabricate interior wall partition [4C]
Fasten wood strips to purlins [2C]
2-day break
Fabricate timber trusses [4C]
Excavate [4L]
Fabricate exterior doors [2C]
2-day break
Const. plywood ext. wall panel [4C]
Forms, rebar & bolts for col ftgs [4C,2I,2L]
Place drain pipes [SUB]
Pour footings [1C,2L]
Cure & strip footings (start)
Erect steel cols & vert brace [4I]
Backfill, compact & grade slab [2L]
Erect trusses [4I]
Forms, rebar & drains floor slab [4C,2I]
Fab & erect frames @ truss pans [2C,2I]
Pour slab [1C,2L]
Erect steel purlins [4I]
Cure slab
Place red bridging & weld [4I]
Erect ext. wall panels [4C]
Nail planks to purlins [2C]
Erect doors [2C]
Waterproof & insulate joints [2L]
Lay tar paper on planks [2L]
Paint ext. walls [SUB]
Erect corrugated roofing [2C]
Erect interior wall partitions [4C]
Cleanup [4L]
Cure & strip footings (end) [1L]
Row
Group Name
1 Carpenters 4 4 1 4 4 4 4 4 4 4 3 4 4 2 2 4 4 4 4 4 2 4
2 Ironworkers 2 4 4 2 2 4 4
3 Laborers 4 2 2 1 2 2 2 2 2 4 4
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
D
JAN
1997
1998
Start Date 01JAN98
Finish Date 28JAN98
Data Date 01JAN98
Run Date 19JUN03 15:50
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Early Bar
Float Bar
Progress Bar
Critical Activity
WARE
Sheet 1 of 1
Warehouse Project (Before Change Order)
Leveled by P3, With Splits: T=28 days
Act5=6d(1W,2B,3W); Act8=5d(1W,2B,2W)
P3 splits Act 8 differently from Fondahl's paper:
P3 : 3 days = 1day + 2 days
Fondahl: 3 days = 2 days + 1 day
Thus, the TF for Act. 4 to 8B shown in Fondahl's paper are different from those in P3: "Alternate Optimum"

ID	Description	T	Pred	TF	FF
1	Site survey & material list	1		0	0
2	Material & equipment to site	3	1	0	0
3	Fabricate interior wall partition [4C]	2	2	4d	4d
4	Fasten wood strips to purlins [2C]	2	2	7d	3d
5	Fabricate timber trusses [4C]	1	2	9d	2d
6	Excavate [4L]	1	2	0	0
7	Fabricate exterior doors [2C]	2	2	11d	11d
8	Const. plywood ext. wall panel [4C]	1	2	6d	2d
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	6	0	0
10	Place drain pipes [SUB]	1	6	5d	5d
11	Pour footings [1C,2L]	1	9	0	0
12	Cure & strip footings (start)	3	11	0	0
13	Erect steel cols & vert brace [4I]	1	12B	2d	0
14	Backfill, compact & grade slab [2L]	2	10, 12B	0	0
15	Erect trusses [4I]	1	13, 5B	5d	1d
16	Forms, rebar & drains floor slab [4C,2I]	1	14	0	0
17	Fab & erect frames @ truss pans [2C,2I]	1	15	4d	0
18	Pour slab [1C,2L]	1	13, 16	0	0
19	Erect steel purlins [4I]	1	17, 4	4d	0
20	Cure slab	6	18	0	0
21	Place red bridging & weld [4I]	1	19	4d	0
22	Erect ext. wall panels [4C]	2	20, 8B	0	0
23	Nail planks to purlins [2C]	2	21	4d	0
24	Erect doors [2C]	1	22, 7	0	0
25	Waterproof & insulate joints [2L]	1	22	0	0
26	Lay tar paper on planks [2L]	1	23	4d	3d
27	Paint ext. walls [SUB]	2	24, 25	0	0
28	Erect corrugated roofing [2C]	2	26	1d	1d
29	Erect interior wall partitions [4C]	1	20, 26, 3	0	0
30	Cleanup [4L]	2	27, 28, 29	0	0
12E	Cure & strip footings (end) [1L]	1	12	0	0
5B	Fabricate timber trusses [4C	3	5	7d	2d
8B	Const. plywood ext. wall panel [4C]	2	8	4d	4d



ID	Description	Units	Display: Quantity
C	Carpenters	CA	4 4 1 4 4 4 4 4 4 4 3 4 4 2 2 4 4 4 4 4 2 4
I	Ironworkers	IW	2 4 4 2 2 4 4
L	Laborers	LB	4 2 2 1 2 2 2 2 4 4

-1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
DAY

Start date	01JAN98
Finish date	28JAN98
Data date	01JAN98
Run date	19JUN03
Page number	1A
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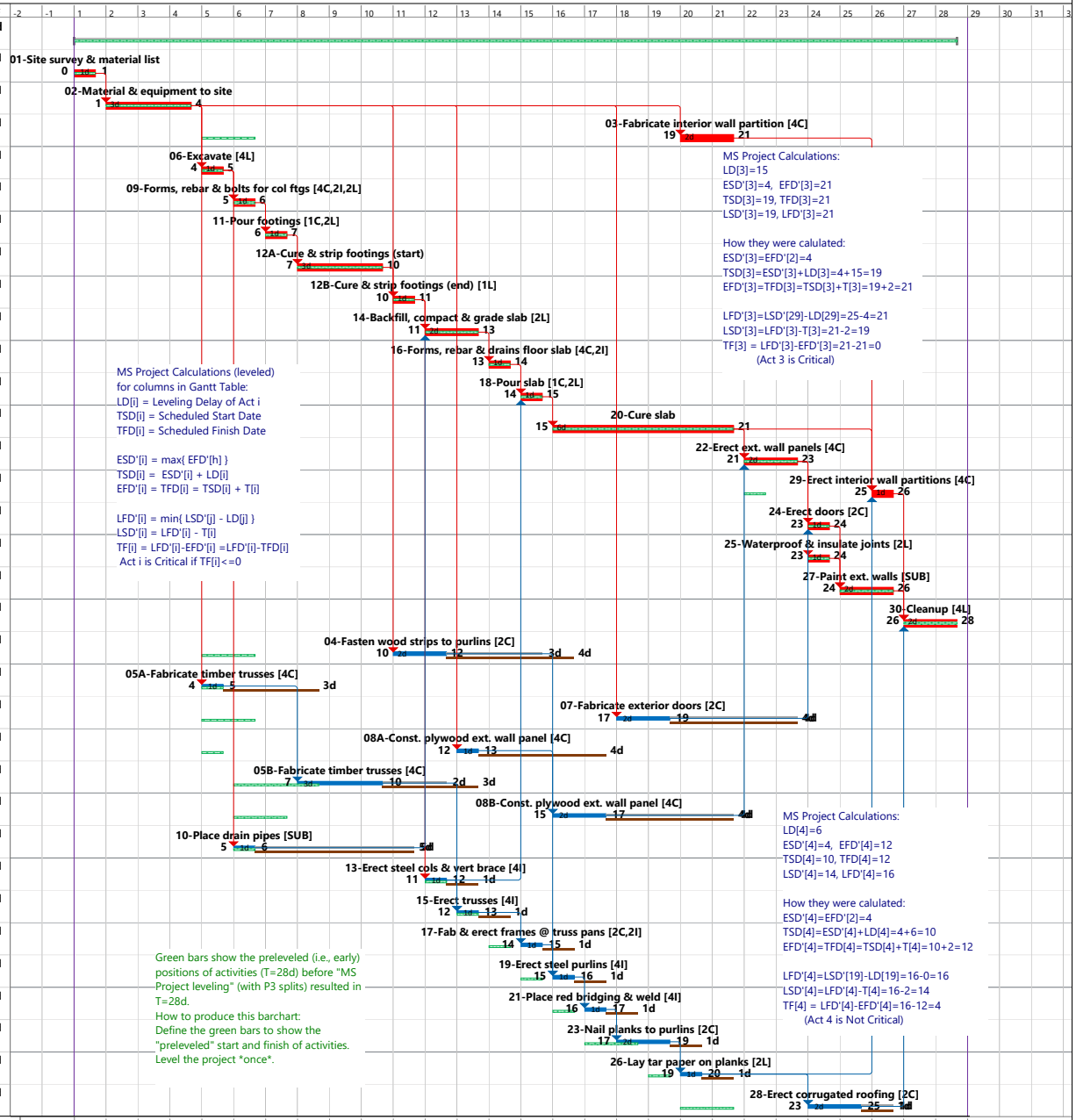
Warehouse Project (Before C.O.)
Levelled by SureTrak with P3 Splits for Act 8: T=28d
T5 = 1 + 3 = 4d, T8 = 1 + 2 = 3d

P3 splits Act 8 differently from Fondahl's paper:
P3 : T8 = 1 + 2 = 3 days
Fondahl: T8 = 2 + 1 = 3 days
Hence, TF are different: "Alternate Optimum"

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone poin

MS Project Pro | Project: Warehouse Project | Date: 11/15/21

ID	Act	Pred	T	Lev	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**28d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
3	03-Fabricate interior wall partition [4C]	2	2d	15ed	4	19	19	21	21	21	0d	0d
6	06-Excavate [4L]	2	1d	0ed	4	4	4	5	5	5	0d	0d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	0ed	5	5	5	6	6	6	0d	0d
11	11-Pour footings [1C,2L]	9	1d	0ed	6	6	6	7	7	7	0d	0d
12	12A-Cure & strip footings (start)	11	3d	0ed	7	7	7	10	10	10	0d	0d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	10	10	10	11	11	11	0d	0d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	11	11	11	13	13	13	0d	0d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	13	13	13	14	14	14	0d	0d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	14	14	14	15	15	15	0d	0d
20	20-Cure slab	18	6d	0ed	15	15	15	21	21	21	0d	0d
22	22-Erect ext. wall panels [4C]	20,33	2d	0ed	21	21	21	23	23	23	0d	0d
29	29-Erect interior wall partitions [4C]	3,20,26	1d	4ed	21	25	25	26	26	26	0d	0d
24	24-Erect doors [2C]	7,22	1d	0ed	23	23	23	24	24	24	0d	0d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	23	23	23	24	24	24	0d	0d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	24	24	24	26	26	26	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	26	26	26	28	28	28	0d	0d
4	04-Fasten wood strips to purlins [2C]	2	2d	6ed	4	10	14	12	12	16	3d	4d
5	05A-Fabricate timber trusses [4C]	2	1d	0ed	4	4	7	5	5	8	0d	3d
7	07-Fabricate exterior doors [2C]	2	2d	13ed	4	17	21	19	19	23	4d	4d
8	08A-Const. plywood ext. wall panel [4C]	2	1d	8ed	4	12	16	13	13	17	0d	4d
32	05B-Fabricate timber trusses [4C]	5	3d	2ed	5	7	10	10	10	13	2d	3d
33	08B-Const. plywood ext. wall panel [4C]	8	2d	2ed	13	15	19	17	17	21	4d	4d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	10	6	6	11	5d	5d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	11	11	12	12	12	13	0d	1d
15	15-Erect trusses [4I]	13,32	1d	0ed	12	12	13	13	13	14	0d	1d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	1ed	13	14	15	15	15	16	0d	1d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	15	15	16	16	16	17	0d	1d
21	21-Place red bridging & weld [4I]	19	1d	0ed	16	16	17	17	17	18	0d	1d
23	23-Nail planks to purlins [2C]	21	2d	0ed	17	17	18	19	19	20	0d	1d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	19	19	20	20	20	21	0d	1d
28	28-Erect corrugated roofing [2C]	26	2d	3ed	20	23	24	25	25	26	1d	1d



MS Project Calculations:
LD[3]=15
ESD'[3]=4, EFD'[3]=21
TSD[3]=19, TFD[3]=21
LSD'[3]=19, LFD'[3]=21

How they were calulated:
ESD'[3]=EFD'[2]=4
TSD[3]=ESD'[3]+LD[3]=4+15=19
EFD'[3]=TFD[3]=TSD[3]+T[3]=19+2=21

LFD'[3]=LSD'[29]-LD[29]=25-4=21
LSD'[3]=LFD'[3]-T[3]=21-2=19
TF[3] = LFD'[3]-EFD'[3]=21-21=0
(Act 3 is Critical)

MS Project Calculations (leveled)
for columns in Gantt Table:
LD[i] = Leveling Delay of Act i
TSD[i] = Scheduled Start Date
TFD[i] = Scheduled Finish Date

ESD'[i] = max{ EFD'[h] }
TSD[i] = ESD'[i] + LD[i]
EFD'[i] = TFD[i] = TSD[i] + T[i]

LFD'[i] = min{ LSD'[j] - LD[j] }
LSD'[i] = LFD'[i] - T[i]
TF[i] = LFD'[i]-EFD'[i] =LFD'[i]-TFD[i]
Act i is Critical if TF[i]<=0

MS Project Calculations:
LD[4]=6
ESD'[4]=4, EFD'[4]=12
TSD[4]=10, TFD[4]=12
LSD'[4]=14, LFD'[4]=16

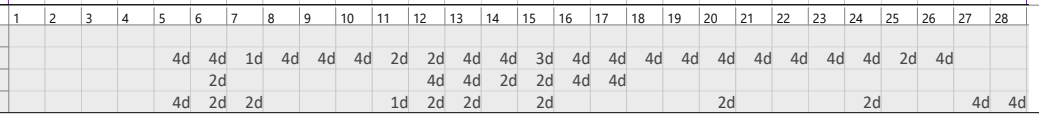
How they were calulated:
ESD'[4]=EFD'[2]=4
TSD[4]=ESD'[4]+LD[4]=4+6=10
EFD'[4]=TFD[4]=TSD[4]+T[4]=10+2=12

LFD'[4]=LSD'[19]-LD[19]=16-0=16
LSD'[4]=LFD'[4]-T[4]=16-2=14
TF[4] = LFD'[4]-EFD'[4]=16-12=4
(Act 4 is Not Critical)

Green bars show the preleveled (i.e., early) positions of activities (T=28d) before "MS Project leveling" (with P3 splits) resulted in T=28d.
How to produce this barchart:
Define the green bars to show the "preleveled" start and finish of activities.
Level the project *once*.

Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu".
If you find this too difficult, you can print and submit the two reports separately.

ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	78d	Work
3	Ironworkers	22d	Work
2	Laborers	27d	Work



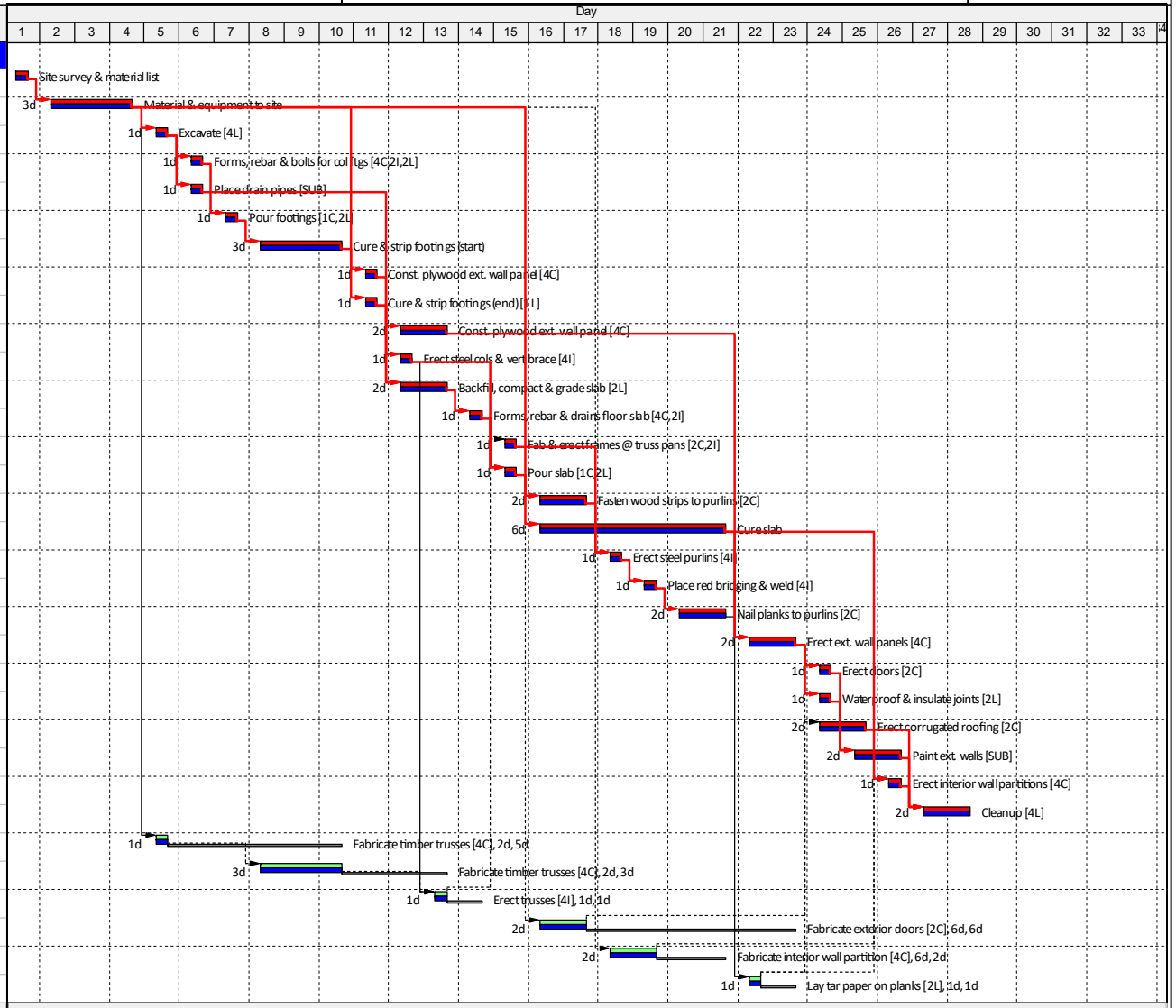
_Lab6 Gantt Chart - P3 Splits
Sorted by: Critical, Preleved Start, Name

Leveled by MS Project using P3 splits - Project duration T=28d
Act 5: T5 = 4d; P3 split into: T5A = 1d, Break = 2d, T5B = 3d
Act 8: T8 = 3d; P3 split into T8A = 1d, Break = 2d, T8B = 2d

Course: CEE538
User: P.G. Ioannou

Primavera P6 Professional R20.12	Project: Warehouse-P3 Splits-TF-leveling-T=28d	Layout: 2021F-Lab6.3-TF Leveling-P3 Splits	Date: 14-11-21

ID	Act	Pred	Orig Dur	Start	Finish	FF	TF
Warehouse-P3 Splits-TF-leveling-T=28d			28d	01-11-21	28-11-21	0d	0d
01	Site survey & material list		1d	01-11-21	01-11-21	0d	-10d
02	Material & equipment to site	01	3d	02-11-21	04-11-21	0d	-10d
06	Excavate [4L]	02	1d	05-11-21	05-11-21	0d	-10d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	06-11-21	06-11-21	0d	-10d
10	Place drain pipes [SUB]	06	1d	06-11-21	06-11-21	5d	-5d
11	Pour footings [1C,2L]	09	1d	07-11-21	07-11-21	0d	-10d
12A	Cure & strip footings (start)	11	3d	08-11-21	10-11-21	0d	-10d
08A	Const. plywood ext. wall panel [4C]	02	1d	11-11-21	11-11-21	0d	-4d
12B	Cure & strip footings (end) [1L]	12A	1d	11-11-21	11-11-21	0d	-10d
08B	Const. plywood ext. wall panel [4C]	08A	2d	12-11-21	13-11-21	8d	-4d
13	Erect steel cols & vert brace [4I]	12B	1d	12-11-21	12-11-21	0d	-7d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	12-11-21	13-11-21	0d	-10d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	14-11-21	14-11-21	0d	-10d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	15-11-21	15-11-21	2d	0d
18	Pour slab [1C,2L]	13, 16	1d	15-11-21	15-11-21	0d	-9d
04	Fasten wood strips to purlins [2C]	02	2d	16-11-21	17-11-21	0d	-2d
20	Cure slab	18	6d	16-11-21	21-11-21	0d	-6d
19	Erect steel purlins [4I]	04, 17	1d	18-11-21	18-11-21	0d	-2d
21	Place red bridging & weld [4I]	19	1d	19-11-21	19-11-21	0d	-2d
23	Nail planks to purlins [2C]	21	2d	20-11-21	21-11-21	0d	-2d
22	Erect ext. wall panels [4C]	20, 08B	2d	22-11-21	23-11-21	0d	-6d
24	Erect doors [2C]	07, 22	1d	24-11-21	24-11-21	0d	0d
25	Waterproof & insulate joints [2L]	22	1d	24-11-21	24-11-21	0d	0d
28	Erect corrugated roofing [2C]	26	2d	24-11-21	25-11-21	1d	0d
27	Paint ext. walls [SUB]	24, 25	2d	25-11-21	26-11-21	0d	0d
29	Erect interior wall partitions [4C]	03, 20, 26	1d	26-11-21	26-11-21	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	27-11-21	28-11-21	0d	0d
05A	Fabricate timber trusses [4C]	02	1d	05-11-21	05-11-21	2d	5d
05B	Fabricate timber trusses [4C]	05A	3d	08-11-21	10-11-21	2d	3d
15	Erect trusses [4I]	13, 05B	1d	13-11-21	13-11-21	1d	1d
07	Fabricate exterior doors [2C]	02	2d	16-11-21	17-11-21	6d	6d
03	Fabricate interior wall partition [4C]	02	2d	18-11-21	19-11-21	6d	2d
26	Lay tar paper on planks [2L]	23	1d	22-11-21	22-11-21	1d	1d



Activity ID	Activity Name	Start	Finish	Remaining Units	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Total		05-11-21	28-11-21						8	8	3	4	4	4	5	10	10	6	7	4	4	8	8	2	2	6	4	6	2	4	4	4					
Resource ID Name: WARE - Root Resour		05-11-21	28-11-21						8	8	3	4	4	4	5	10	10	6	7	4	4	8	8	2	2	6	4	6	2	4	4	4					
Resource ID Name: C Carpenters		05-11-21	26-11-21						4	4	1	4	4	4	4	4	4	4	3	4	4	4	4	2	2	4	4	4	2	4							
Resource ID Name: I Ironworkers		06-11-21	19-11-21							2						4	4	2	2			4	4														
Resource ID Name: L Laborers		05-11-21	28-11-21						4	2	2				1	2	2		2							2		2			4	4					

Critical Rem Work
Remaining Work
Early Bar
Float Bar

Repeated TF-leveling by P6: T= 28d; using P3 splits: 'Act 5(4d) = 5A(1d) & 5B(3d)'; 'Act 8(3d) = 8A(1d) & 8B(2d)'
Set: "Preserve scheduled early and late dates": No; "Leveling Priorities": "Total Float (Ascending)"
Sorted by: Critical, Early Start, Activity ID

Course: CEE538
User: P.G. Ioannou

CASE STUDY: THE WAREHOUSE PROJECT[1]

You are the successful contractor for a warehouse project. Based on the original bidding documents, you have developed the activity list shown in Table 1 which includes the activity number, the activity name, the activity duration, the set of predecessor activities, and the daily resource requirements.

The contract for this project requires completion within 28 working days after the *Notice to Proceed* and calls for liquidated damages for late completion at the rate of $1,000 per working day. The *General Conditions* of the contract include a clause identical to *SP-13* of the *U.S. Postal Service Specifications* (shown below). Following contract award, you submitted a computer printout of your master schedule that shows completion of the work in 28 working days.

At the time of the notice to proceed, the owner issues a *Change Order* and informs you that he has redesigned some of the work. This increases the duration of Activities 3, 7, 8, and 29 as follows:

Activity	Original Duration	New Duration	Duration Increase	Free Float (for comparison)
03-Fabricate interior wall partition [4C]	2d	8d	6d	15d
07-Fabricate exterior doors [2C]	2d	7d	5d	17d
08-Const. plywood ext. wall panel [4C]	3d	12d	9d	14d
29-Erect interior wall partitions [4C]	1d	4d	3d	4d

The owner agrees to pay the additional costs caused by the *Change Order* but refuses to allow any time extension. At this point, you become concerned about possible resource availability. **Each day you can only provide 4 carpenters (C), 4 ironworkers (I), and 4 laborers (L).**

Part 1

- Develop a schedule showing that you could complete the original project (before the *Change Order*) within 28 days without exceeding your resource availability constraints.
- Why do you think the owner denied granting the revised project any time extension?

Part 2

You now realize that you can no longer meet the 28-day schedule under the *Change Order* requirements. Thus, you accept the *Change Order* under protest, indicating that you do not agree with the owner's denial of time extension.

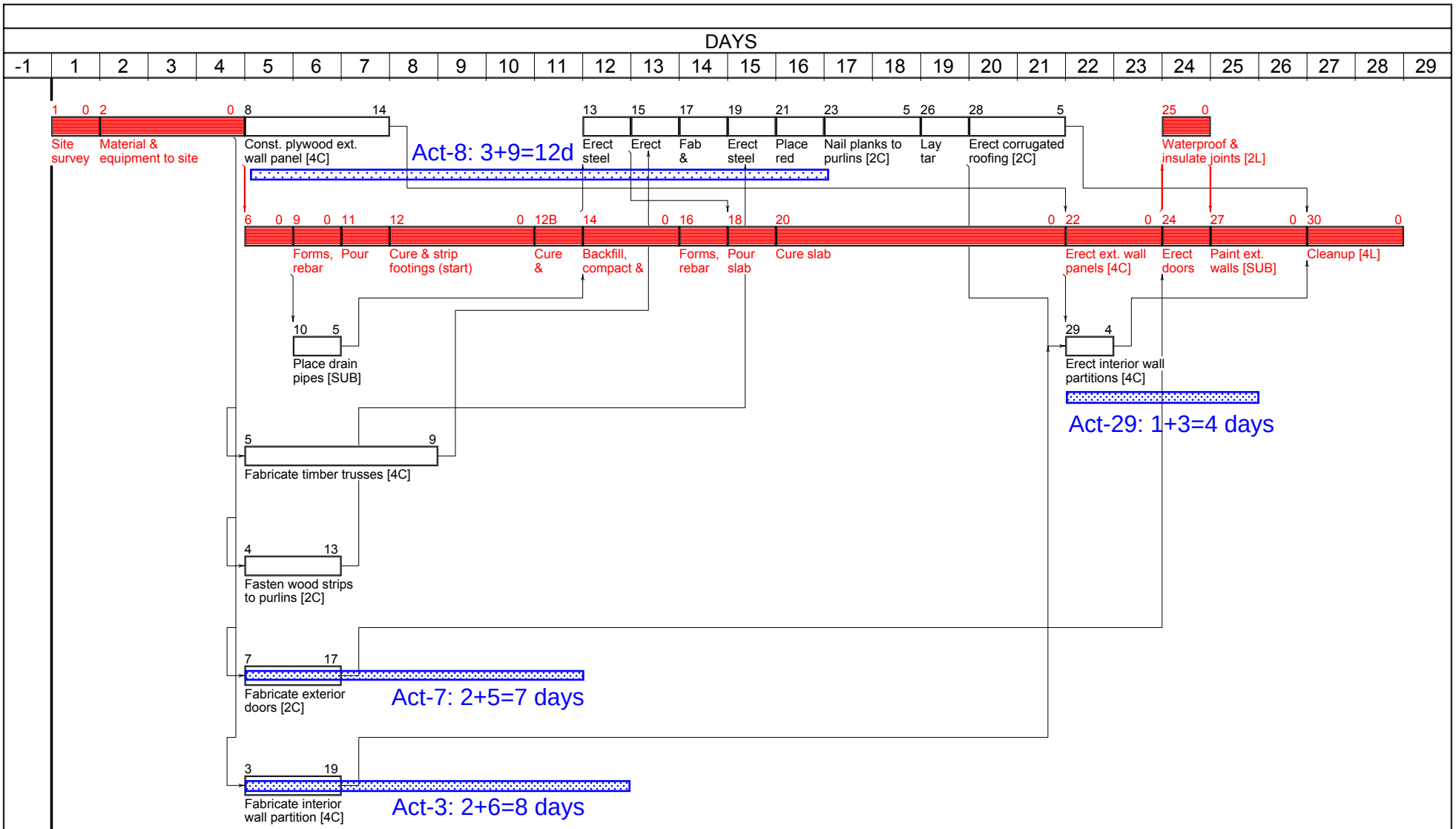
- How much time extension should you claim? Document your claim by producing a schedule using the revised activity duration estimates and subject to the above resource availability constraints. Knowing that this schedule will be challenged by the owner's top engineering talent, you must develop the shortest schedule possible.
- How much time extension should you claim if you could split activities?

Example 1: *General Services Administration* (GSA) Specification

"Adjustment of Contract Completion Time

The contractor acknowledges and agrees that actual delays in activities which, according to the computer-produced calendar-dated schedule, do not affect any contract completion date shown by the critical path in the network, do not have any effect on the contract completion date or dates and therefore will not be the basis for a change therein."

[1] Adapted by P.G. Ioannou from
"*Seabee Planner's and Estimator's Handbook*"
NavDocks-P-405, Dept. of the Navy, Bureau of Yards and Docks, Washington DC, circa 1960.



Plot Date	19JUN03
Data Date	1JAN98
Project Start	1JAN98
Project Finish	28JAN98

(c) Primavera Systems, Inc.

act id — inactive — tf

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

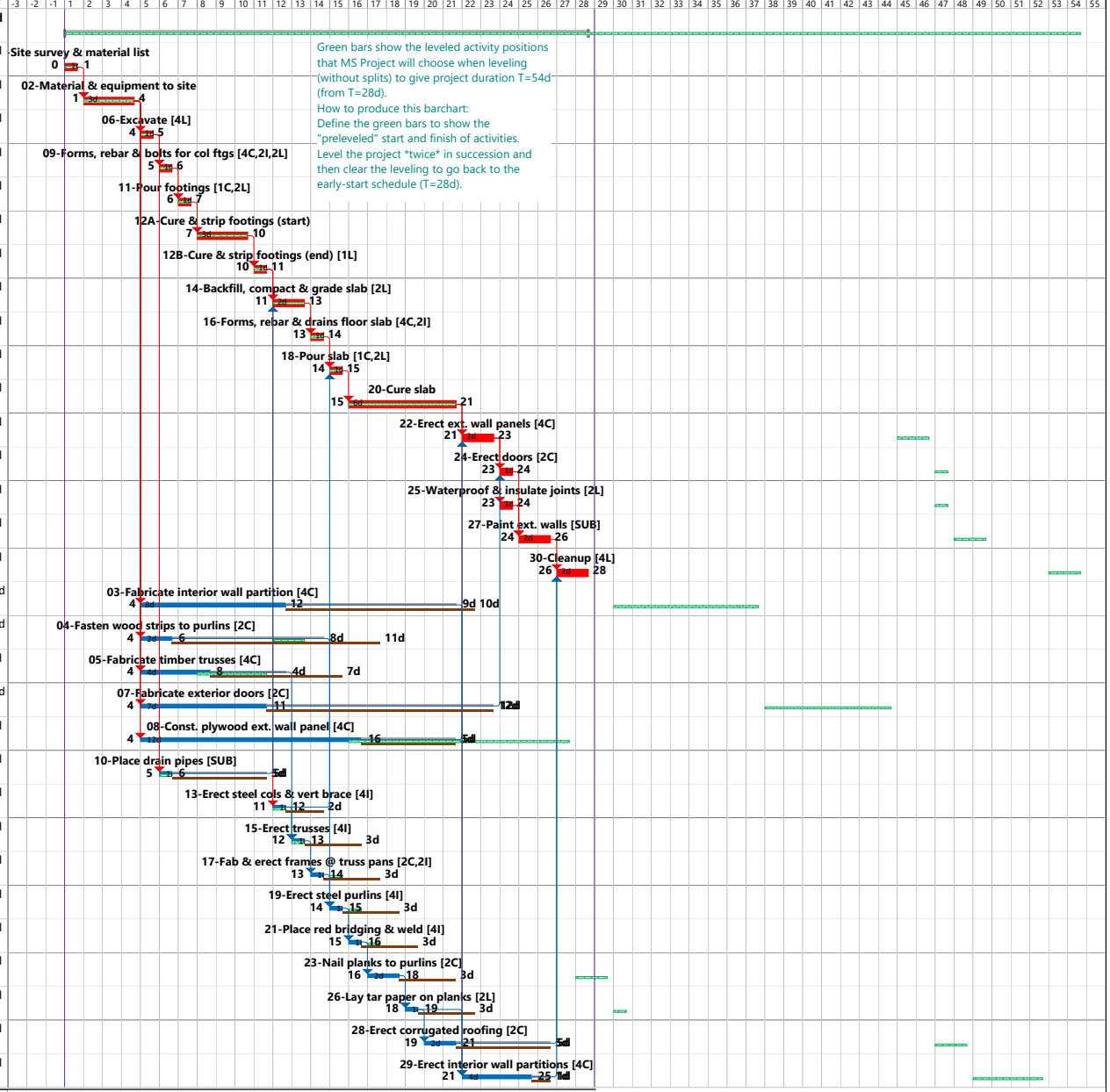
Sheet 1 of 1

P3 Time-Scaled Precedence Network
Duration: T = 28 days
Warehouse Project (Fondahl)

Early Start Schedule

Date	Revision	Checked	Approved

ID	Act	Pred	T	Lev	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**28d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
6	06-Excavate [4L]	2	1d	0ed	4	4	4	5	5	5	0d	0d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	0ed	5	5	5	6	6	6	0d	0d
11	11-Pour footings [1C,2L]	9	1d	0ed	6	6	6	7	7	7	0d	0d
12	12A-Cure & strip footings (start)	11	3d	0ed	7	7	7	10	10	10	0d	0d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	10	10	10	11	11	11	0d	0d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	11	11	11	13	13	13	0d	0d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	13	13	13	14	14	14	0d	0d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	14	14	14	15	15	15	0d	0d
20	20-Cure slab	18	6d	0ed	15	15	15	21	21	21	0d	0d
22	22-Erect ext. wall panels [4C]	20,8	2d	0ed	21	21	21	23	23	23	0d	0d
24	24-Erect doors [2C]	7,22	1d	0ed	23	23	23	24	24	24	0d	0d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	23	23	23	24	24	24	0d	0d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	24	24	24	26	26	26	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	26	26	26	28	28	28	0d	0d
3	03-Fabricate interior wall partition [4C]	2	8d	0ed	4	4	14	12	12	22	9d	10d
4	04-Fasten wood strips to purlins [2C]	2	2d	0ed	4	4	15	6	6	17	8d	11d
5	05-Fabricate timber trusses [4C]	2	4d	0ed	4	4	11	8	8	15	4d	7d
7	07-Fabricate exterior doors [2C]	2	7d	0ed	4	4	16	11	11	23	12d	12d
8	08-Const. plywood ext. wall panel [4C]	2	12d	0ed	4	4	9	16	16	21	5d	5d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	10	6	6	11	5d	5d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	11	11	13	12	12	14	0d	2d
15	15-Erect trusses [4I]	13,5	1d	0ed	12	12	15	13	13	16	0d	3d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	0ed	13	13	16	14	14	17	0d	3d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	14	14	17	15	15	18	0d	3d
21	21-Place red bridging & weld [4I]	19	1d	0ed	15	15	18	16	16	19	0d	3d
23	23-Nail planks to purlins [2C]	21	2d	0ed	16	16	19	18	18	21	0d	3d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	18	18	21	19	19	22	0d	3d
28	28-Erect corrugated roofing [2C]	26	2d	0ed	19	19	24	21	21	26	5d	5d
29	29-Erect interior wall partitions [4C]	3,20,26	4d	0ed	21	21	22	25	25	26	1d	1d

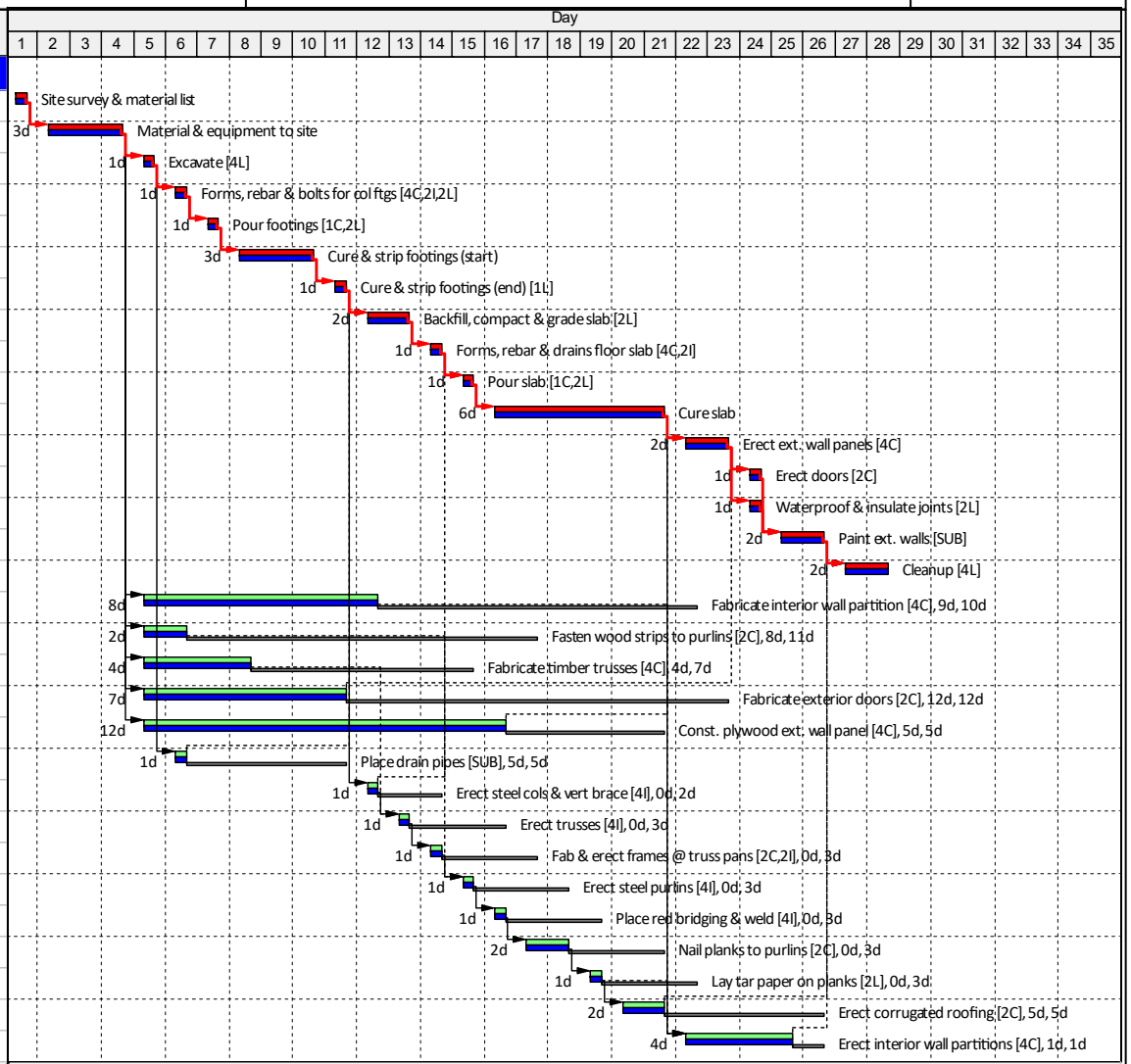


Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu".
If you find this too difficult, you can print and submit the two reports separately.

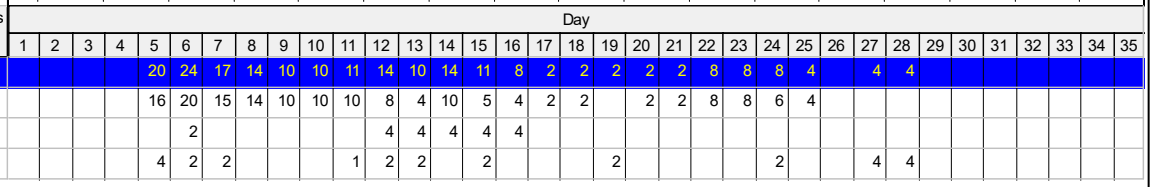
ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	160d	Work
2	Ironworkers	22d	Work
3	Laborers	27d	Work

Primavera P6 Professional R20.12	Project: WH-After CO-Unleveled-T=28d	Layout: 2021F-Lab6.4-CO-Unleveled	Date: 01-12-21

ID	Act	Pred	Orig Dur	Start	Finish	FF	TF
WH-After CO-Unleveled-T=28d			28d	01-11-21	28-11-21	0d	0d
01	Site survey & material list		1d	01-11-21	01-11-21	0d	0d
02	Material & equipment to site	01	3d	02-11-21	04-11-21	0d	0d
06	Excavate [4L]	02	1d	05-11-21	05-11-21	0d	0d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	06-11-21	06-11-21	0d	0d
11	Pour footings [1C,2L]	09	1d	07-11-21	07-11-21	0d	0d
12A	Cure & strip footings (start)	11	3d	08-11-21	10-11-21	0d	0d
12B	Cure & strip footings (end) [1L]	12A	1d	11-11-21	11-11-21	0d	0d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	12-11-21	13-11-21	0d	0d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	14-11-21	14-11-21	0d	0d
18	Pour slab [1C,2L]	13, 16	1d	15-11-21	15-11-21	0d	0d
20	Cure slab	18	6d	16-11-21	21-11-21	0d	0d
22	Erect ext. wall panels [4C]	20, 08	2d	22-11-21	23-11-21	0d	0d
24	Erect doors [2C]	07, 22	1d	24-11-21	24-11-21	0d	0d
25	Waterproof & insulate joints [2L]	22	1d	24-11-21	24-11-21	0d	0d
27	Paint ext. walls [SUB]	24, 25	2d	25-11-21	26-11-21	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	27-11-21	28-11-21	0d	0d
03	Fabricate interior wall partition [4C]	02	8d	05-11-21	12-11-21	9d	10d
04	Fasten wood strips to purlins [2C]	02	2d	05-11-21	06-11-21	8d	11d
05	Fabricate timber trusses [4C]	02	4d	05-11-21	08-11-21	4d	7d
07	Fabricate exterior doors [2C]	02	7d	05-11-21	11-11-21	12d	12d
08	Const. plywood ext. wall panel [4C]	02	12d	05-11-21	16-11-21	5d	5d
10	Place drain pipes [SUB]	06	1d	06-11-21	06-11-21	5d	5d
13	Erect steel cols & vert brace [4I]	12B	1d	12-11-21	12-11-21	0d	2d
15	Erect trusses [4I]	13, 05	1d	13-11-21	13-11-21	0d	3d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	14-11-21	14-11-21	0d	3d
19	Erect steel purlins [4I]	04, 17	1d	15-11-21	15-11-21	0d	3d
21	Place red bridging & weld [4I]	19	1d	16-11-21	16-11-21	0d	3d
23	Nail planks to purlins [2C]	21	2d	17-11-21	18-11-21	0d	3d
26	Lay tar paper on planks [2L]	23	1d	19-11-21	19-11-21	0d	3d
28	Erect corrugated roofing [2C]	26	2d	20-11-21	21-11-21	5d	5d
29	Erect interior wall partitions [4C]	03, 20, 26	4d	22-11-21	25-11-21	1d	1d



Activity ID	Remaining Units	Remaining Units
Total	209	
Resource ID Name: C Carpenters	160	
Resource ID Name: I Ironworkers	22	
Resource ID Name: L Laborers	27	

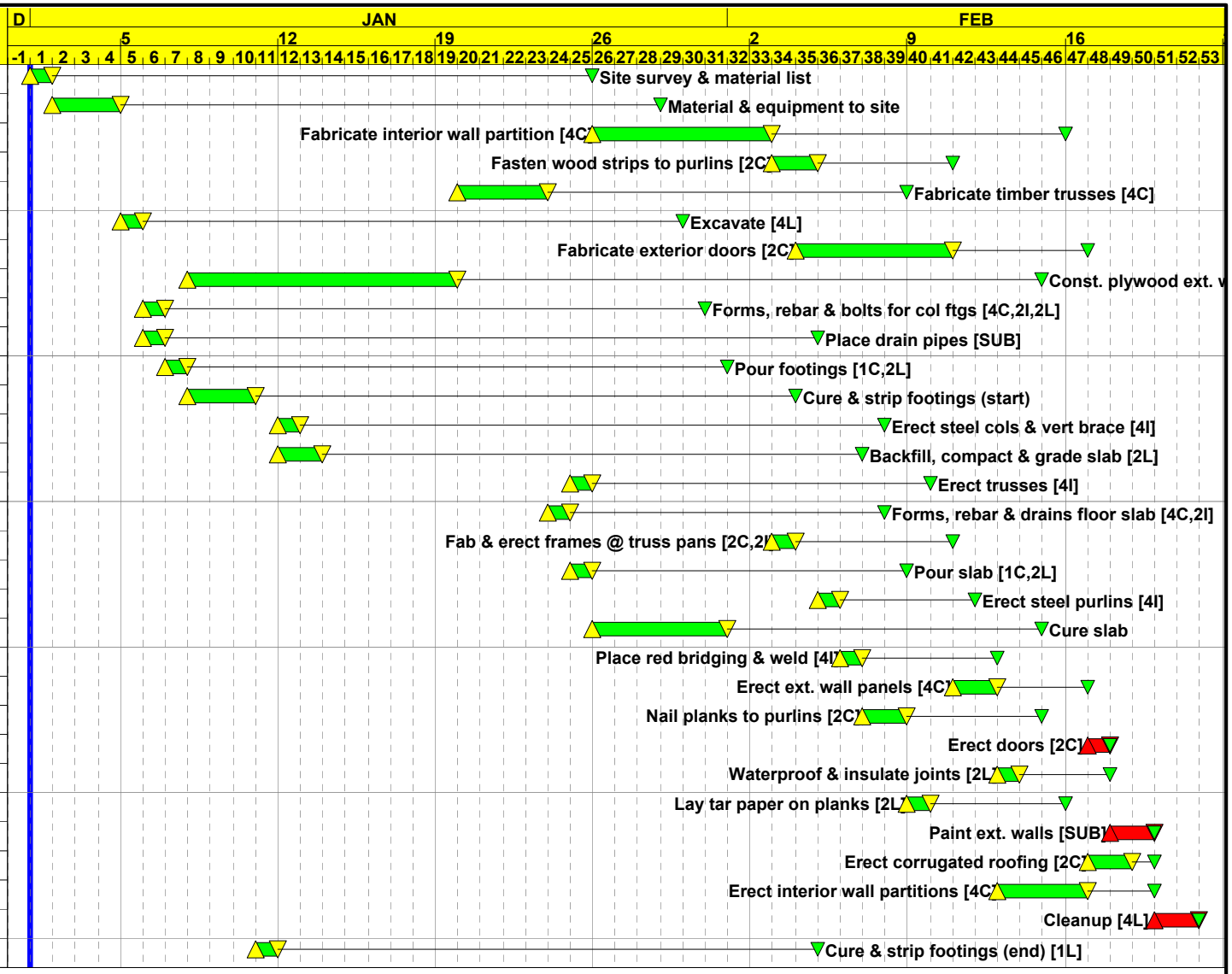


Critical Rem Work
Remaining Work
Early Bar
Float Bar

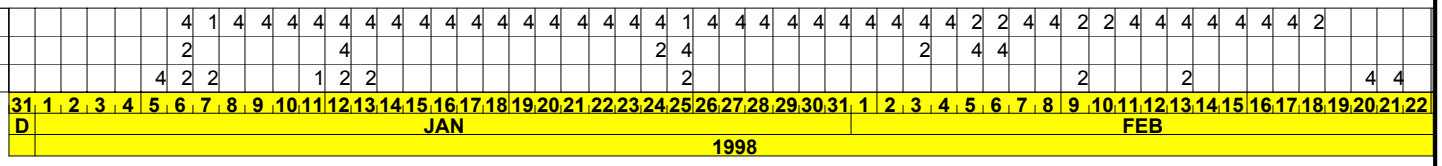
Date	Revision	Check...	Approved
11-18-21	After Change Order - Early-Start Schedule, Unleveled, T=28d	PGI	PGI
	(To print all 3 res rows in sprdsht, select them on screen)		
	Sorted by: Critical, Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

ID	Act	T	TF	FF
1	Site survey & material list	1	24	0
2	Material & equipment to site	3	24	0
3	Fabricate interior wall partition [4C]	8	13	10
4	Fasten wood strips to purlins [2C]	2	6	0
5	Fabricate timber trusses [4C]	4	16	1
6	Excavate [4L]	1	24	0
7	Fabricate exterior doors [2C]	7	6	6
8	Const. plywood ext. wall panel [4C]	12	26	22
9	Forms, rebar & bolts for col ftgs [4C,2I,2L]	1	24	0
10	Place drain pipes [SUB]	1	29	5
11	Pour footings [1C,2L]	1	24	0
12	Cure & strip footings (start)	3	24	0
13	Erect steel cols & vert brace [4I]	1	26	12
14	Backfill, compact & grade slab [2L]	2	24	10
15	Erect trusses [4I]	1	15	8
16	Forms, rebar & drains floor slab [4C,2I]	1	14	0
17	Fab & erect frames @ truss pans [2C,2I]	1	7	1
18	Pour slab [1C,2L]	1	14	0
19	Erect steel purlins [4I]	1	6	0
20	Cure slab	6	14	10
21	Place red bridging & weld [4I]	1	6	0
22	Erect ext. wall panels [4C]	2	4	0
23	Nail planks to purlins [2C]	2	6	0
24	Erect doors [2C]	1	0	0
25	Waterproof & insulate joints [2L]	1	4	4
26	Lay tar paper on planks [2L]	1	6	3
27	Paint ext. walls [SUB]	2	0	0
28	Erect corrugated roofing [2C]	2	1	1
29	Erect interior wall partitions [4C]	4	3	3
30	Cleanup [4L]	2	0	0
12B	Cure & strip footings (end) [1L]	1	24	0



Row	Group Name
1	Carpenters
2	Ironworkers
3	Laborers



Start Date 01JAN98
Finish Date 21FEB98
Data Date 01JAN98
Run Date 19JUN03 16:11

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Early Bar
Float Bar
Progress Bar
Critical Activity

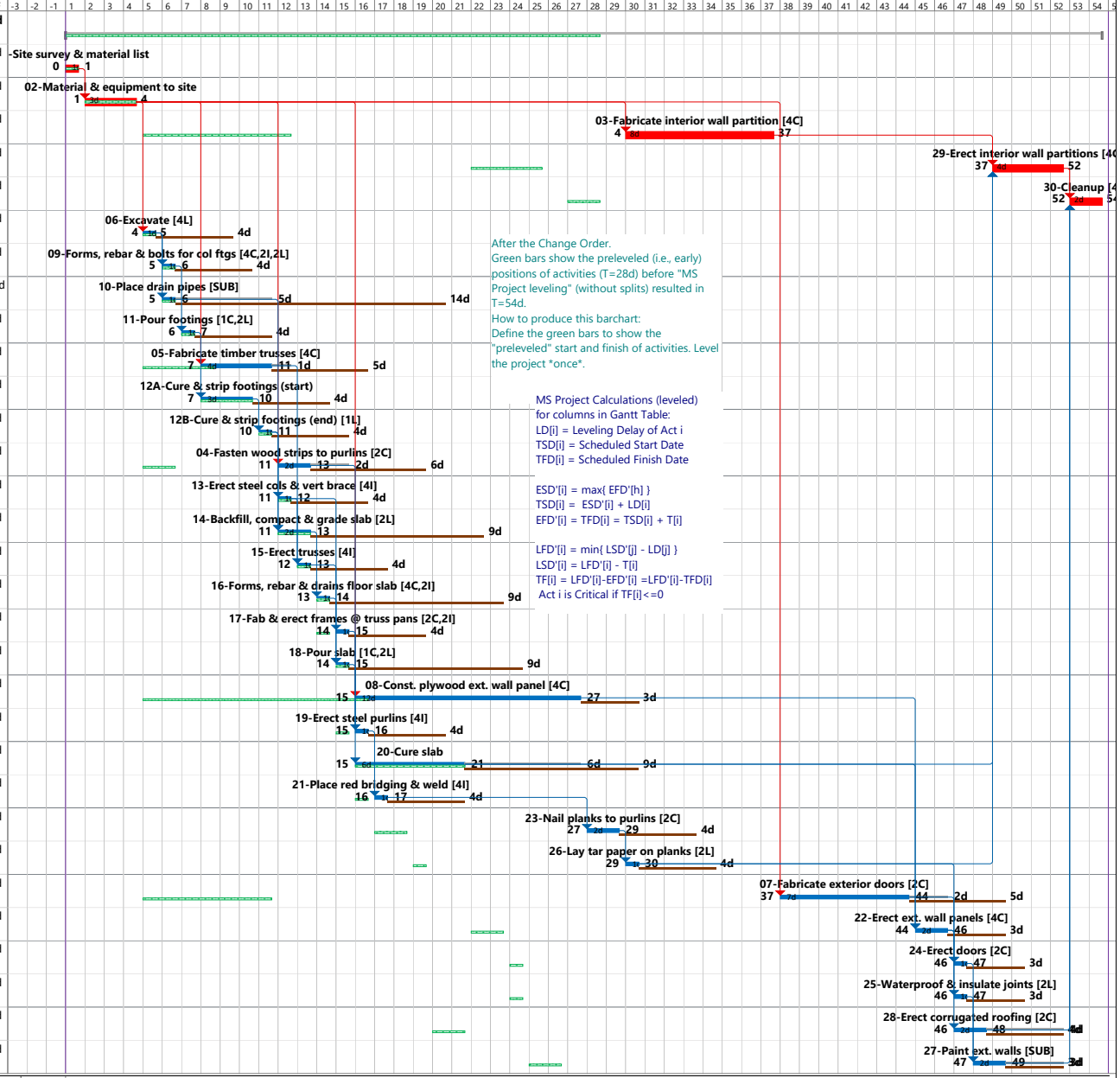
WARE Sheet 1 of 1

Warehouse Project (After Change Order)
Levelled by P3, No Splits: T=52d
T3=2+6=8, T7=2+5=7, T8=3+9=12, T29=1+3=4

Project Duration = 52 days
Same as found by Fondahl using P3 and no splits

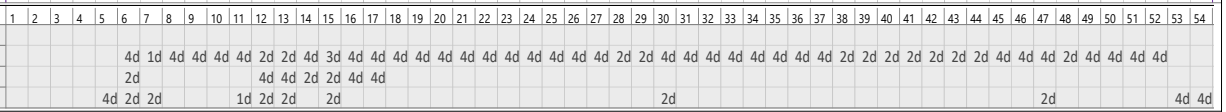
MS Project Pro | Project: Warehouse Project | Date: 12/1/21

ID	Act	Pred	T	Lev	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**54d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
3	03-Fabricate interior wall partition [4C]	2	8d	25ed	4	29	29	37	37	37	0d	0d
29	29-Erect interior wall partitions [4C]	3,20,26	4d	11ed	37	48	48	52	52	52	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	52	52	52	54	54	54	0d	0d
6	06-Excavate [4L]	2	1d	0ed	4	4	8	5	5	9	0d	4d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	0ed	5	5	9	6	6	10	0d	4d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	19	6	6	20	5d	14d
11	11-Pour footings [1C,2L]	9	1d	0ed	6	6	10	7	7	11	0d	4d
5	05-Fabricate timber trusses [4C]	2	4d	3ed	4	7	12	11	11	16	1d	5d
12	12A-Cure & strip footings (start)	11	3d	0ed	7	7	11	10	10	14	0d	4d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	10	10	14	11	11	15	0d	4d
4	04-Fasten wood strips to purlins [2C]	2	2d	7ed	4	11	17	13	13	19	2d	6d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	11	11	15	12	12	16	0d	4d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	11	11	20	13	13	22	0d	9d
15	15-Erect trusses [4I]	13,5	1d	0ed	12	12	16	13	13	17	0d	4d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	13	13	22	14	14	23	0d	9d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	1ed	13	14	18	15	15	19	0d	4d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	14	14	23	15	15	24	0d	9d
8	08-Const. plywood ext. wall panel [4C]	2	12d	11ed	4	15	18	27	27	30	0d	3d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	15	15	19	16	16	20	0d	4d
20	20-Cure slab	18	6d	0ed	15	15	24	21	21	30	6d	9d
21	21-Place red bridging & weld [4I]	19	1d	0ed	16	16	20	17	17	21	0d	4d
23	23-Nail planks to purlins [2C]	21	2d	10ed	17	27	31	29	29	33	0d	4d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	29	29	33	30	30	34	0d	4d
7	07-Fabricate exterior doors [2C]	2	7d	33ed	4	37	42	44	44	49	2d	5d
22	22-Erect ext. wall panels [4C]	20,8	2d	17ed	27	44	47	46	46	49	0d	3d
24	24-Erect doors [2C]	7,22	1d	0ed	46	46	49	47	47	50	0d	3d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	46	46	49	47	47	50	0d	3d
28	28-Erect corrugated roofing [2C]	26	2d	16ed	30	46	50	48	48	52	4d	4d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	47	47	50	49	49	52	3d	3d



Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu".
If you find this too difficult, you can print and submit the two reports separately.

ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	160d	Work
2	Ironworkers	22d	Work
3	Laborers	27d	Work



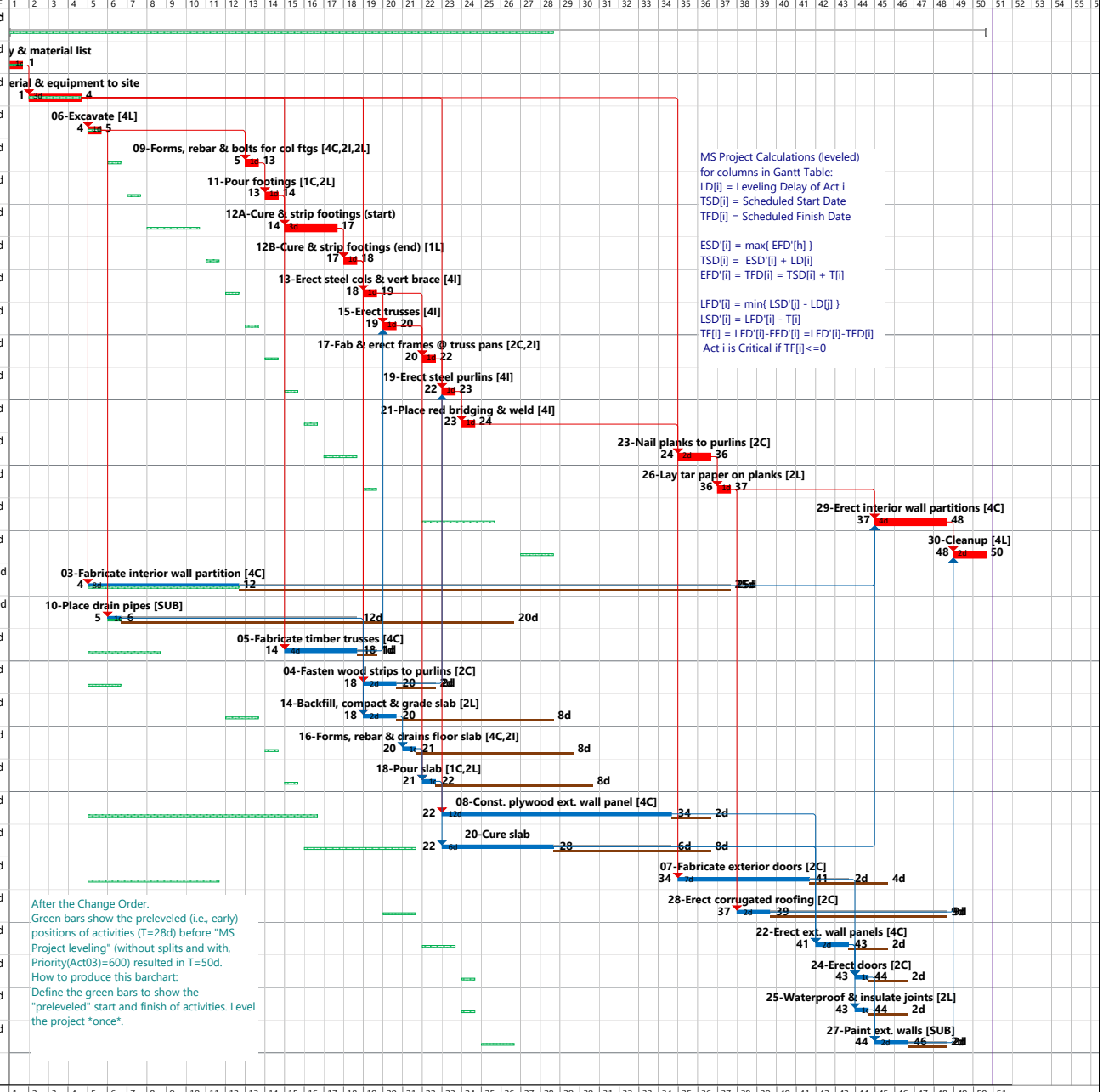
_Lab6 CO Gantt Chart Leveled
Sorted by: Critical, Start, Name

After Change Order --- Leveled by MS Project (default, no splits) --- Project duration T=54d

Course: CEE538
User: P.G. Ioannou

MS Project Pro | Project: Warehouse Project | Date: 12/1/21

ID	Act	Pred	T	Lev	ESD	TSD	LSD	EFD	TFD	LFD	FF	TF
0	**Warehouse Project**		**50d**	**0ed**	**0**	**0**	**0**	**0**	**0**	**0**	**0d**	**0d**
1	01-Site survey & material list		1d	0ed	0	0	0	1	1	1	0d	0d
2	02-Material & equipment to site	1	3d	0ed	1	1	1	4	4	4	0d	0d
6	06-Excavate [4L]	2	1d	0ed	4	4	4	5	5	5	0d	0d
9	09-Forms, rebar & bolts for col ftgs [4C,2I,2L]	6	1d	7ed	5	12	12	13	13	13	0d	0d
11	11-Pour footings [1C,2L]	9	1d	0ed	13	13	13	14	14	14	0d	0d
12	12A-Cure & strip footings (start)	11	3d	0ed	14	14	14	17	17	17	0d	0d
31	12B-Cure & strip footings (end) [1L]	12	1d	0ed	17	17	17	18	18	18	0d	0d
13	13-Erect steel cols & vert brace [4I]	31	1d	0ed	18	18	18	19	19	19	0d	0d
15	15-Erect trusses [4I]	13,5	1d	0ed	19	19	19	20	20	20	0d	0d
17	17-Fab & erect frames @ truss pans [2C,2I]	15	1d	1ed	20	21	21	22	22	22	0d	0d
19	19-Erect steel purlins [4I]	4,17	1d	0ed	22	22	22	23	23	23	0d	0d
21	21-Place red bridging & weld [4I]	19	1d	0ed	23	23	23	24	24	24	0d	0d
23	23-Nail planks to purlins [2C]	21	2d	10ed	24	34	34	36	36	36	0d	0d
26	26-Lay tar paper on planks [2L]	23	1d	0ed	36	36	36	37	37	37	0d	0d
29	29-Erect interior wall partitions [4C]	3,20,26	4d	7ed	37	44	44	48	48	48	0d	0d
30	30-Cleanup [4L]	27,28,29	2d	0ed	48	48	48	50	50	50	0d	0d
3	03-Fabricate interior wall partition [4C]	2	8d	0ed	4	4	29	12	12	37	25d	25d
10	10-Place drain pipes [SUB]	6	1d	0ed	5	5	25	6	6	26	12d	20d
5	05-Fabricate timber trusses [4C]	2	4d	10ed	4	14	15	18	18	19	1d	1d
4	04-Fasten wood strips to purlins [2C]	2	2d	14ed	4	18	20	20	20	22	2d	2d
14	14-Backfill, compact & grade slab [2L]	10,31	2d	0ed	18	18	26	20	20	28	0d	8d
16	16-Forms, rebar & drains floor slab [4C,2I]	14	1d	0ed	20	20	28	21	21	29	0d	8d
18	18-Pour slab [1C,2L]	13,16	1d	0ed	21	21	29	22	22	30	0d	8d
8	08-Const. plywood ext. wall panel [4C]	2	12d	18ed	4	22	24	34	34	36	0d	2d
20	20-Cure slab	18	6d	0ed	22	22	30	28	28	36	6d	8d
7	07-Fabricate exterior doors [2C]	2	7d	30ed	4	34	38	41	41	45	2d	4d
28	28-Erect corrugated roofing [2C]	26	2d	0ed	37	37	46	39	39	48	9d	9d
22	22-Erect ext. wall panels [4C]	20,8	2d	7ed	34	41	43	43	43	45	0d	2d
24	24-Erect doors [2C]	7,22	1d	0ed	43	43	45	44	44	46	0d	2d
25	25-Waterproof & insulate joints [2L]	22	1d	0ed	43	43	45	44	44	46	0d	2d
27	27-Paint ext. walls [SUB]	24,25	2d	0ed	44	44	46	46	46	48	2d	2d

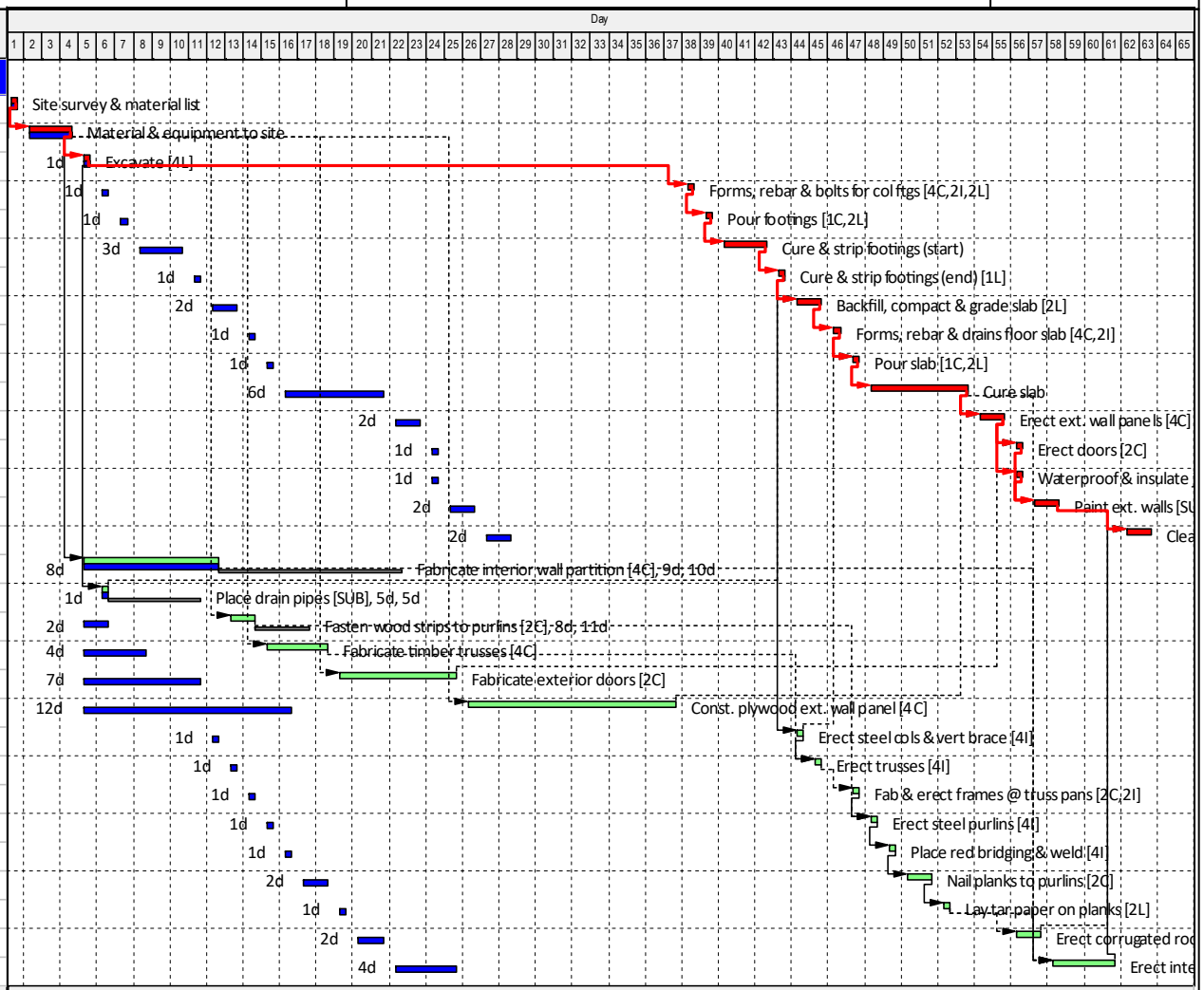


ID	Resource Name	Work	Details
	Unassigned	0d	Work
1	Carpenters	160d	Work
2	Ironworkers	22d	Work
3	Laborers	27d	Work

Note: The Resource Usage spreadsheet, shown on the right, was printed to pdf separately and was pasted to the pdf for the Gantt Chart using "Bluebeam Revu". If you find this too difficult, you can print and submit the two reports separately.

Primavera P6 Professional R20.12	Project: WH-After CO-No Splits-Def Lvl-T=63d	Layout: 2021F-Lab6.5-CO-Default_Leveling	Date: 01-12-21

ID	Act	Pred	Orig Dur	FF	TF
WH-After CO-No Splits-Def Lvl-T=63d			63d	0d	0d
01	Site survey & material list		1d	0d	0d
02	Material & equipment to site	01	3d	0d	0d
06	Excavate [4L]	02	1d	0d	0d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	0d	0d
11	Pour footings [1C,2L]	09	1d	0d	0d
12A	Cure & strip footings (start)	11	3d	0d	0d
12B	Cure & strip footings (end) [1L]	12A	1d	0d	0d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	0d	0d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	0d	0d
18	Pour slab [1C,2L]	13, 16	1d	0d	0d
20	Cure slab	18	6d	0d	0d
22	Erect ext. wall panels [4C]	20, 08	2d	0d	0d
24	Erect doors [2C]	07, 22	1d	0d	0d
25	Waterproof & insulate joints [2L]	22	1d	0d	0d
27	Paint ext. walls [SUB]	24, 25	2d	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	0d	0d
03	Fabricate interior wall partition [4C]	02	8d	9d	10d
10	Place drain pipes [SUB]	06	1d	5d	5d
04	Fasten wood strips to purlins [2C]	02	2d	8d	11d
05	Fabricate timber trusses [4C]	02	4d	4d	7d
07	Fabricate exterior doors [2C]	02	7d	12d	12d
08	Const. plywood ext. wall panel [4C]	02	12d	5d	5d
13	Erect steel cols & vert brace [4I]	12B	1d	0d	2d
15	Erect trusses [4I]	13, 05	1d	0d	3d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	0d	3d
19	Erect steel purlins [4I]	04, 17	1d	0d	3d
21	Place red bridging & weld [4I]	19	1d	0d	3d
23	Nail planks to purlins [2C]	21	2d	0d	3d
26	Lay tar paper on planks [2L]	23	1d	0d	3d
28	Erect corrugated roofing [2C]	26	2d	5d	5d
29	Erect interior wall partitions [4C]	03, 20, 26	4d	1d	1d



Activity ID		Remaining Units	Budgeted Units
Total		209	
Resource ID Name: C	Carpenters	160	
Resource ID Name: I	Ironworkers	22	
Resource ID Name: L	Laborers	27	

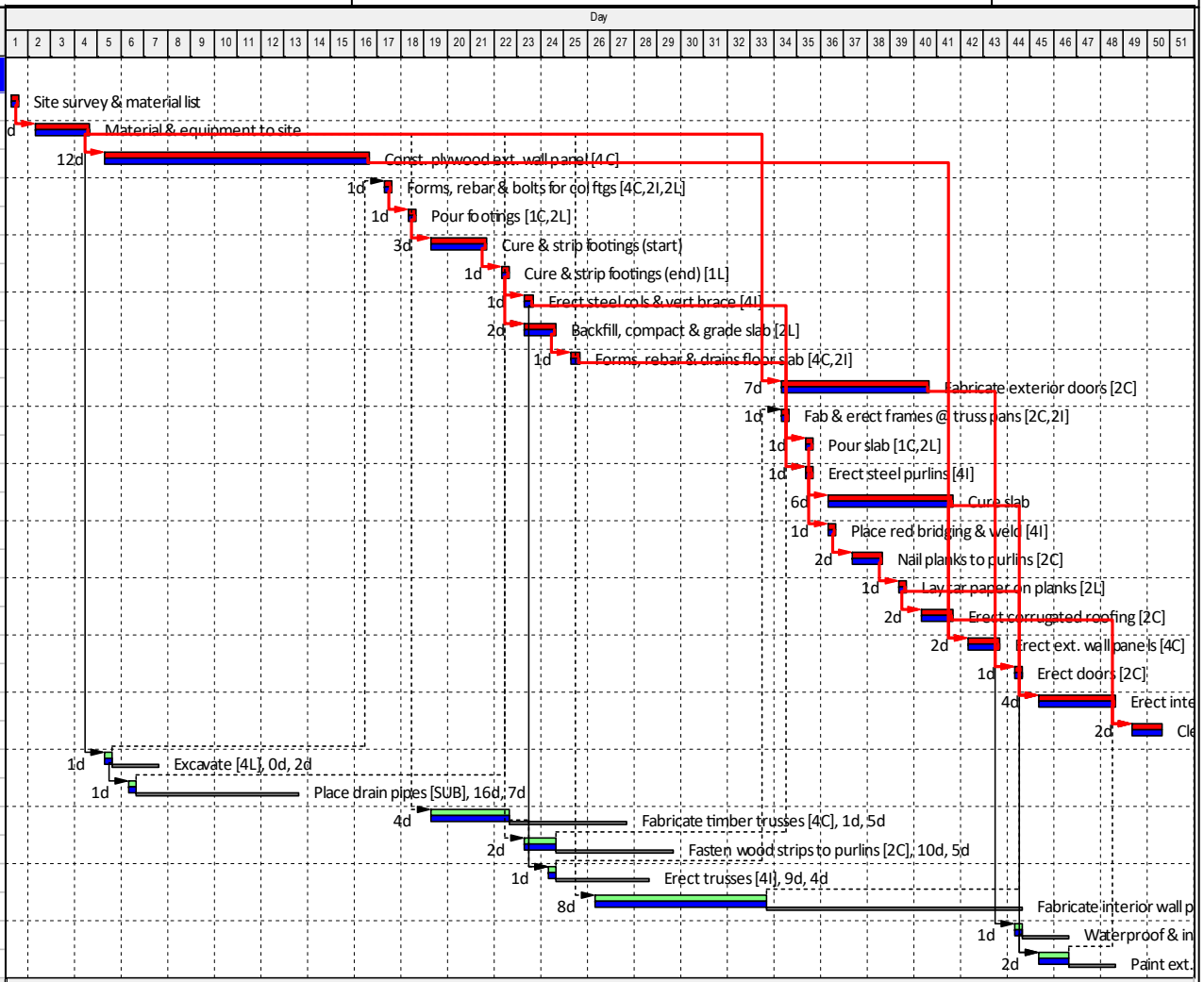
Critical Rem Work
Float Bar
Remaining Work
Early Bar

Date	Revision	Check...	Approved
1-12-21	After Change Order - Default leveling, T=63d	PGI	PGI
	(To print all 3 res rows in sprdsht, select them on screen)		
	Sorted by: Critical, Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

Primavera P6 Professional R20.12	Project: WH-After CO-No Splits-TF Lvl-T=50d	Layout: 2021F-Lab6.6-CO-TF_Leveling	Date: 01-12-21

ID	Act	Pred	Orig Dur	FF	TF
WH-After CO-No Splits-TF Lvl-T=50d			50d	0d	0d
01	Site survey & material list		1d	0d	-9d
02	Material & equipment to site	01	3d	0d	-9d
08	Const. plywood ext. wall panel [4C]	02	12d	25d	-9d
09	Forms, rebar & bolts for col ftgs [4C,2I,2L]	06	1d	0d	-9d
11	Pour footings [1C,2L]	09	1d	0d	-9d
12A	Cure & strip footings (start)	11	3d	0d	-9d
12B	Cure & strip footings (end) [1L]	12A	1d	0d	-9d
13	Erect steel cols & vert brace [4I]	12B	1d	0d	-1d
14	Backfill, compact & grade slab [2L]	10, 12B	2d	0d	-9d
16	Forms, rebar & drains floor slab [4C,2I]	14	1d	9d	-9d
07	Fabricate exterior doors [2C]	02	7d	3d	-17d
17	Fab & erect frames @ truss pans [2C,2I]	15	1d	0d	-5d
18	Pour slab [1C,2L]	13, 16	1d	0d	-12d
19	Erect steel purlins [4I]	04, 17	1d	0d	-5d
20	Cure slab	18	6d	0d	-12d
21	Place red bridging & weld [4I]	19	1d	0d	-5d
23	Nail planks to purlins [2C]	21	2d	0d	-5d
26	Lay tar paper on planks [2L]	23	1d	0d	-5d
28	Erect corrugated roofing [2C]	26	2d	7d	-5d
22	Erect ext. wall panels [4C]	20, 08	2d	0d	-12d
24	Erect doors [2C]	07, 22	1d	0d	-8d
29	Erect interior wall partitions [4C]	03, 20, 26	4d	0d	0d
30	Cleanup [4L]	27, 28, 29	2d	0d	0d
06	Excavate [4L]	02	1d	0d	2d
10	Place drain pipes [SUB]	06	1d	16d	7d
05	Fabricate timber trusses [4C]	02	4d	1d	5d
04	Fasten wood strips to purlins [2C]	02	2d	10d	5d
15	Erect trusses [4I]	13, 05	1d	9d	4d
03	Fabricate interior wall partition [4C]	02	8d	11d	11d
25	Waterproof & insulate joints [2L]	22	1d	0d	2d
27	Paint ext. walls [SUB]	24, 25	2d	2d	2d



Activity ID	Remaining Units	Budgeted Units
Total	209	
Resource ID Name: C Carpenters	160	
Resource ID Name: I Ironworkers	22	
Resource ID Name: L Laborers	27	

Critical Rem Work
Float Bar
Remaining Work
Early Bar

Date	Revision	Check...	Approved
1-12-21	After Change Order - Repeated TF leveling, T=50d	PGI	PGI
	(To print all 3 res rows in sprdsht, select them on screen)		
	Sorted by: Critical, Start, Activity ID		

Course: CEE538
User: P.G. Ioannou

TABLE 2. Resource Leveling Effects on Criticality–Warehouse Project[1]

MSP Act ID (1)	P6 Act ID (1)	Total float before leveling (2)	Original critical (3)	Total float used in rescheduling (4)	Theoretical remaining total float (5)	Actual remaining total float (6)	Critical after leveling (7)
1	1	0	C	-	-	-	C
2	2	0	C	-	-	-	C
3	3	19	-	15	4	0	C
4	4	13	-	2	11	0	C
5 (1d)	5A (1d)	9	-	0	9	0	C
32 (3d)	5B (3d)	9	-	3	6	0	C
6	6	0	C	-	-	-	C
7	7	17	-	12	5	1	-
8 (1d)	8A (1d)	14	-	7	7	0	C
33 (2d)	8B (2d)	14	-	9	5	1	-
9	9	0	C	-	-	-	C
10	10	5	-	0	5	5	-
11	11	0	C	-	-	-	C
12 (3d)	12A (3d)	0	C	-	-	-	C
31 (1d)	12B (1d)	0	C	-	-	-	C
13	13	2	-	0	2	0	C
14	14	0	C	-	-	-	C
15	15	5	-	0	5	0	C
16	16	0	C	-	-	-	C
17	17	5	-	1	4	0	C
18	18	0	C	-	-	-	C
19	19	5	-	1	4	0	C
20	20	0	C	-	-	-	C
21	21	5	-	1	4	0	C
22	22	0	C	-	-	-	C
23	23	5	-	1	4	0	C
24	24	0	C	-	-	-	C
25	25	0	C	-	-	-	C
26	26	5	-	1	4	3	-
27	27	0	C	-	-	-	C
28	28	5	-	4	1	0	C
29	29	4	-	4	0	0	C
30	30	0	C	-	-	-	C

[1] Table 2 is a revised version of Table 1 from the paper:
Fondahl, J. (1991). "*The Development of the Construction Engineer: Past Progress and Future Problems*" J. Constr. Eng. Mgmt., ASCE, Vol 117, No 3, pp 380-392.

Main changes: In Table 2, each of the three activities 5, 8, and 12 has been split into two activities as follows:

Original Activity (Dur)		**Split MS Project Activities** (Dur)	**Split P6 Activities** (Dur)
5 (4d)	=	**5** (1d) + **32** (3d)	**5A** (1d) + **5B** (3d)
8 (3d)	=	**8** (1d) + **33** (2d)	**8A** (1d) + **8B** (2d)
12 (4d)	=	**12** (3d) + **31** (1d)	**12A** (3d) + **12B** (1d)

This enables MS Project and P6 (neither of which can split activities automatically when leveling resources) to "split" into two activities each of the three activities 5, 8, and 12, as described by Fondahl (1991).

Provide short answers to the following (easy) questions:

Use the MS Project Resource Usage report to verify that the Warehouse Project (after the Change Order) has a total amount of 160 mandays of work for the carpenters (more than double the 78 mandays before the Change Order). Consider also the following:

- Activity "*Site survey & material list*" (1d) and its successor activity "*Material & equipment to site*" (3d), must precede all other activities in the network and that both activities do not require any carpenters.
- There is only one finish activity, "*Cleanup*" (2d), which is a successor to all other activities, and it does not require any carpenters, either.

Based on these observations alone,

1. What is the minimum possible duration for the Warehouse Project (even when each of the rest of the activities could be split as many times as might be needed) given that there are only 4 carpenters available?
2. How should these simple observations be presented by the contractor to explain to the project owner the impact of the Change Order on the project schedule and the increase of the project duration from 28d to 50d? Explain.
3. The following table shows the duration of the project (after the change order) produced by MS Project (with default and with priority leveling), P6 (with default and with TF leveling), Fondahl's manual leveling, and P3. What do you conclude?

MS Project Default	MS Project Priority(A03)=600	P6 Pro Default	P6 Pro TF Leveling	Fondahl (Manual)	P3 Leveling
54d	50d	63d	50d	50d	52d

4. Compare the two solutions produced by MS Project. Compare the two solutions produced by P6 Pro. What are some practical conclusions for users of these programs?

Use the following quotes from Fondahl's article to answer the questions below:

"The changes made [by the Change Order] were all within the activity's […] free float periods. [Yet] Because resource restrictions governed, the project was actually extended in duration by almost 80%. In such a situation, it is quite likely that neither contractor nor owner, in the absence of a resource-leveled schedule, would fully appreciate just why the project was gradually turning into a disaster.
This brings up another related problem. *Few of even those who claim to be "CPM experts" fully appreciate the fact that in a resource-restrained schedule the concept of float breaks down and quite often the concept of a critical path breaks down.*"

5. What does Fondahl mean by: "*in a resource-restrained schedule the concept of float breaks down*"?
6. What does Fondahl mean by: "*in a resource-restrained schedule… the concept of a critical path breaks down*"?

"Since almost all construction projects are resource-restrained, at least to some extent, this becomes a source of major problems. The classic legal question in recent years, as well as the subject of numerous professional papers, is, "*Who owns float time*?" It is difficult to claim ownership of something that might not exist or that hasn't been quantified properly."

7. What does Fondahl mean by: "*It is difficult to claim ownership of something that might not exist or that hasn't been quantified properly.*"?

These are fundamental matters that after 30 years still don't seem to be understood.
More importantly, the results shown in these simple problems indicate that the conventional concepts of "*float time"* break down in a resource-constrained project. "*Float times"* may be much less than those computed, or may not exist at all, and *project duration may not be determined by the conventionally calculated critical path*. Again, since almost any construction project either must be resource-leveled to achieve a feasible solution or should be resource-leveled to achieve an economic solution, we have a problem that is almost always present but seems to be universally ignored. Some, and often many, of the conventional CPM data are not valid. The originally calculated network data, including float data, are useful as a basis for establishing and applying priority rules in heuristic leveling procedures. *However, once leveling has been performed, float times may have little meaning.*

8. What does Fondahl mean by: "*The originally calculated network data, including float data, are useful as a basis for establishing and applying priority rules in heuristic leveling procedures. However, once leveling has been performed, float times may have little meaning.*"?

Provide short answers to the following questions related to Fondahl's Article

9. Consider observations (5), (7), and (8). What do you conclude about floats in resource-restrained construction schedules?
10. Given your answer above, what is the best way to define "*Critical Activities*"? (See Fondahl's article for the answer.)
11. Given observation (6), under what (simplifying) conditions does a schedule *really* have a "*Critical Path*", and what then is the appropriate (complete) definition of a "*Critical Path*" (= longest path)?
12. Is there a critical path in your MS Project and P6 schedules after the resources are leveled? Explain your answer.

Lab 6-Part 2 Assignment Deliverables

1. Lab 6 Part 2 Report (one PDF file submitted on Canvas)

Start with a discussion that describes the project and the change order. Describe the five scheduling reports by MS Project and P6 and explain how they were produced and why. Use the following scheduling reports to provide answers to all the numbered questions above.

MS Project: Three "Gantt Chart and Resource Usage" combination reports (like the ones for Part 1) for the 28-day, 54-day, and 50-day schedules (no network report is needed).

P6 Pro: Two "Gantt Chart and Resource Spreadsheet" combination reports (like the ones for Part 1) one for the 63-day schedule and one for the 50-day schedule (i.e., one report for leveling using the default settings and one report for leveling using TF as the leveling criteria).

2. ZIP file (sent through email to photios@umich.edu)

As usual.