Connecting Industry to Mathematics Instruction
NSF ATE Award # 1954291

SOLUTIONS to Student Activity Sheet

Steel Consequences Activity

You are a project manager at SteelFab. You have been assigned to manage the framework construction of an office building in downtown Raleigh. The main objective of a project manager is to make sure your team's steel fabrication and erection is on time and cost effective. You will use the SteelFab: Steel Consequences Spreadsheet to manage the construction project tasks in 4 phases.Complete each Task under each Phase.

Phase 1: Complete the Steel Fabrication Table

The project drawing set has been approved for construction. The drawings indicate that the given numbers of sequences and pieces are needed to construct the framework of the building. As the project manager, you must determine the Fab Duration, Fab Start, and Fab Finish for each sequence.

KEY NOTES
• 8 fabricators work at a time to fabricate a sequence. • Each fabricator works 10 hours per day. • It takes 4 hours to fabricate 1 piece. • A Fab Start of "0" is the first day of the project.

[Task a] Create a formula to calculate Fab Duration for each sequence. Write the relationship in words first. Enter the formula in E4 then fill the column to find the Fab Duration for each sequence. The Total Duration should be the sum for all of the sequences.

Sequence Duration = #pieces x Fab time/work time/#workers

$= 80pcs \times \frac{4hrs}{1\,pc} \times \frac{1\,person}{10\,hrs} \times \frac{1\,day}{8\,people} = 4\,days$ Formula for cell E6 = C4*4/10/8

[Task b] Begin with a Fab Start of "0" for Seq. 1 to create a formula to calculate the Fab Start of the remaining sequences. Write the relationship in words first. Enter the formula in D5 then fill the column.

Seq. 2 Fab Start = Seq. 1 Start + Seq. 1 Duration; D5 = D4 + E4

[Task c] Create a formula to calculate the Fab Finish of each sequence. Write the relationship in words first. Enter the formula in F4 then fill the column.

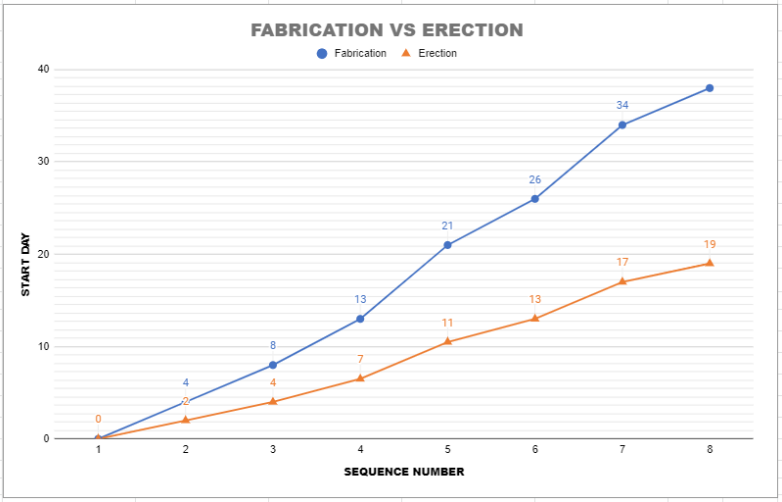
Seq. 1 Fab Finish = Seq. 1 Start + Seq. 1 Duration; F4 = D4 + E4

STEEL FABRICATION TABLE

SEQUENCE	PIECES	FAB START	FAB DURATION (DAYS)	FAB FINISH
1	80	0	4	4
2	80	4	4	8
3	100	8	5	13
4	160	13	8	21
5	100	21	5	26
6	160	26	8	34
7	80	34	4	38
8	80	38	4	42
Total Piece Count	840	Total Duration	42	

ERECTION TABLE

SEQUENCE	PIECES	ERECTION START	ERECTION DURATION	ERECTION FINISH
1	80	0	2	2
2	80	2	2	4
3	100	4	3	7
4	160	7	4	11
5	100	11	3	13
6	160	13	4	17
7	80	17	2	19
8	80	19	2	21
Total Piece Count	840	Total Duration	21	



Phase 2: Initialize the Data

The graph provides a visual representation of the relationship between the fabrication and erection data. Now that your fabrication and erection tables are created, as project manager, you must predict the most efficient erection start day and finish day. In a perfect world there would be no delays, and the two tables would be your fabrication and erection timetable for the entire project.

KEY POINTS

- Begin with both start days set to "0".
- Only manipulate cells D4 (dark blue) and D16 (dark orange) unless noted otherwise.
- Assume 7 day work weeks.

[Task a] What information can you get from the graph?

The blue line represents the Fabrication data. The y-axis indicates the fabrication start day, and the x-axis gives the sequence number.

The orange line represents the Erection data. The x-axis indicates the erection start day, and the x-axis gives the sequence number.

[Task b] Can you identify any issues in the current graph of the data? If so, identify where they occur and why it's an issue.

Issue: The graph shows sequences being erected before the sequence is even fabricated. It also has the Fabrication Start and Erection Start occurring on the same day. The pieces cannot be erected if they have not been made.

[Task c] Assuming erection can begin once fabrication for a sequence is complete, what is the earliest day erection can start if Seq. 1 is completely fabricated?

The earliest erection start date for Seq. 1 is day 4 because it will take 4 days to fabricate Seq. 1.

[Task d] What does your answer to 2c above represent in the Erection table? Where would you enter this value in the Erection table? Enter the value. Explain what is happening in the new graph and what this tells us about what is happening at the jobsite.

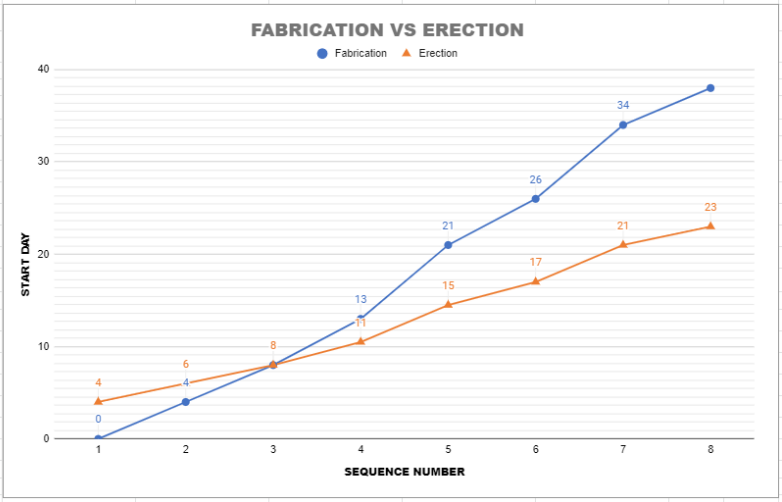
The graph shows that it took 4 days to fabricate Seq. 1. On the 4th day Seq. 1 erection began and was completed in 2 days on day 6. Fabrication for Seq. 2 began on day 4 but was not completed until day 8. This means that workers were at the jobsite with nothing to do. Time is money and both are being wasted. After day 8 fabrication falls way behind the erection schedule.

STEEL FABRICATION TABLE

SEQUENCE	PIECES	FAB START	FAB DURATION (DAYS)	FAB FINISH
1	80	0	4	4
2	80	4	4	8
3	100	8	5	13
4	160	13	8	21
5	100	21	5	26
6	160	26	8	34
7	80	34	4	38
8	80	38	4	42
Total Piece Count	840	Total Duration	42	

ERECTION TABLE

SEQUENCE	PIECES	ERECTION START	ERECTION DURATION	ERECTION FINISH
1	80	4	2	6
2	80	6	2	8
3	100	8	3	11
4	160	11	4	15
5	100	15	3	17
6	160	17	4	21
7	80	21	2	23
8	80	23	2	25
Total Piece Count	840	Total Duration	21	



Phase 3: Address Unforeseen Circumstances

In the real world, we know that problems at the fabrication plant or at the building site will likely occur. As project manager, you must determine how delays affect your timetable.

KEY POINTS

- Phase 3 begins where Phase 2 ends.
- Only manipulate cells D4 (dark blue) and D16 (dark orange) unless noted otherwise.
- Assume 7 day work weeks.

[Task a] Brainstorm a list of potential problems that could occur during the fabrication and erection process that would affect the start and the finish dates of the sequences and the overall project?

Answers are not limited to the following.

- Bad weather
- Illness
- Workers strike
- Material shortages
- Accident at the worksite or plant
- Equipment breaks down

[Task b] The erector welders contracted food poisoning from a food truck. Construction stopped because there were not enough available workers. All workers were able to return to work after 3

days. Based on the erection start date you found in Phase 2c-d, on what day will erection for Seq. 1 now be complete, taking the sick delay into consideration?

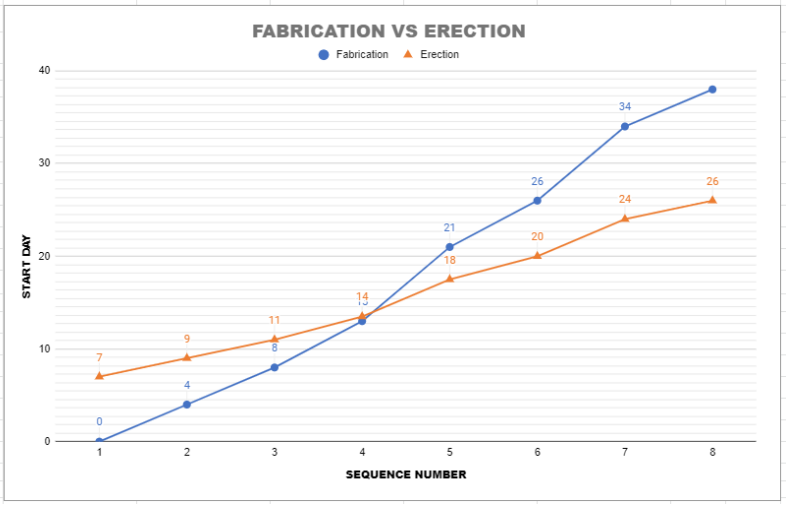
The original start date was day 4. The workers will now begin 3 days later. Day 4 + 3 days = Day 7
If erection begins on day 7 it will be completed on day 9.

STEEL FABRICATION TABLE

SEQUENCE	PIECES	FAB START	FAB DURATION (DAYS)	FAB FINISH
1	80	0	4	4
2	80	4	4	8
3	100	8	5	13
4	160	13	8	21
5	100	21	5	26
6	160	26	8	34
7	80	34	4	38
8	80	38	4	42
Total Piece Count	840	Total Duration	42	

ERECTION TABLE

SEQUENCE	PIECES	ERECTION START	ERECTION DURATION	ERECTION FINISH
1	80	7	2	9
2	80	9	2	11
3	100	11	3	14
4	160	14	4	18
5	100	18	3	20
6	160	20	4	24
7	80	24	2	26
8	80	26	2	28
Total Piece Count	840	Total Duration	21	



[Task c] Analyze the current graph. Is there still an issue? If so, play around with the value in the J4 (dark orange cell) until you find an erection start date that will allow approximately 5 days between Seq. 8 fabrication start and Seq. 8 erection start.

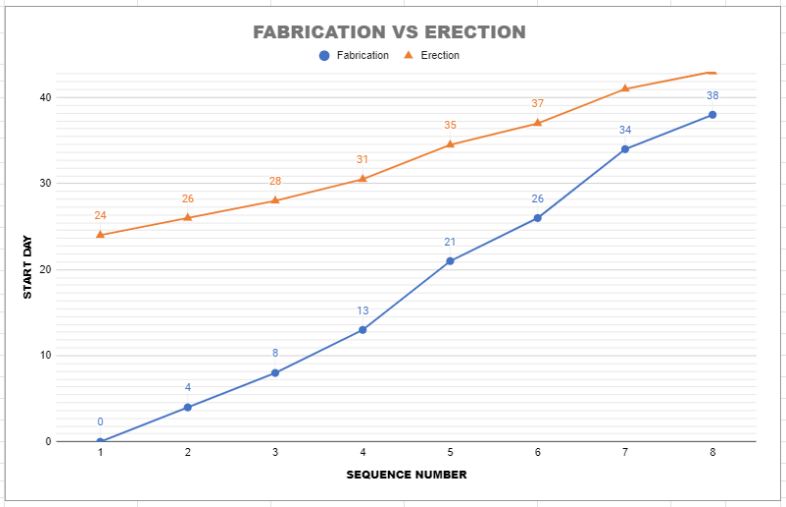
Issue: The graph still shows some sequences being erected before the sequence is fabricated. The company is still losing money. For Seq. 8, Day 24 provides the 5-day window needed, resulting in a Fabrication start date of day 38 and Erection start day of 43. You can see it at the top of the graph and at the bottom of the tables. This window allows ample time for the fabrication of Seq. 8 with an extra day if needed.

STEEL FABRICATION TABLE

SEQUENCE	PIECES	FAB START	FAB DURATION (DAYS)	FAB FINISH
1	80	0	4	4
2	80	4	4	8
3	100	8	5	13
4	160	13	8	21
5	100	21	5	26
6	160	26	8	34
7	80	34	4	38
8	80	38	4	42
Total Piece Count	840	Total Duration	42	

ERECTION TABLE

SEQUENCE	PIECES	ERECTION START	ERECTION DURATION	ERECTION FINISH
1	80	24	2	26
2	80	26	2	28
3	100	28	3	31
4	160	31	4	35
5	100	35	3	37
6	160	37	4	41
7	80	41	2	43
8	80	43	2	45
Total Piece Count	840	Total Duration	21	



[Task d] Analyze how many sequences have been fabricated by the erection start date you found in Phase 3c above.

Based on observations from the graph and table, we can conclude that 4 sequences would be complete and the 5th would have started fabrication.

[Task e] You are allotted 60 days for fabrication and erection. Based on the current table, will you be able to complete the work in this time? How many days will you go over or have to spare? What are the potential economic impacts?

Erection of Seq. 8 finishes on day 45. This would allow you to complete the project and is 15 days less than the 60 days allotted.

[Task f] A tropical storm floods the jobsite and delays the start day of erection by 3 weeks. What is the new end date for all erection to be complete? By how many days over the allotted 60 days will erection run over?

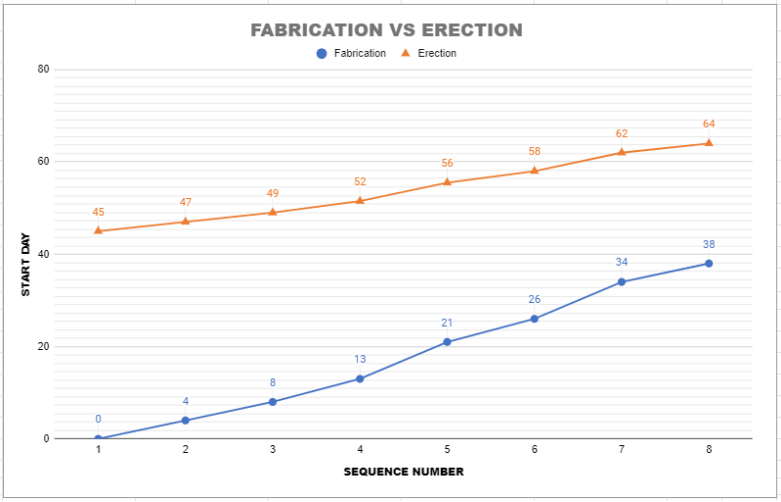
3 weeks would delay the start 21 days, making the new end date day 45 + 21 days = day 66. This would push erection 6 days over the allotted time.

STEEL FABRICATION TABLE

SEQUENCE	PIECES	FAB START	FAB DURATION (DAYS)	FAB FINISH
1	80	0	4	4
2	80	4	4	8
3	100	8	5	13
4	160	13	8	21
5	100	21	5	26
6	160	26	8	34
7	80	34	4	38
8	80	38	4	42
Total Piece Count	840	Total Duration	42	

ERECTION TABLE

SEQUENCE	PIECES	ERECTION START	ERECTION DURATION	ERECTION FINISH
1	80	45	2	47
2	80	47	2	49
3	100	49	3	52
4	160	52	4	56
5	100	56	3	58
6	160	58	4	62
7	80	62	2	64
8	80	64	2	66
Total Piece Count	840	Total Duration	21	



Phase 4: Billing and Turnover

Depending on the size of the project, a project can take several months to construct. If the fabrication and erection times do not align correctly, SteelFab will lose money. Billing invoices are sent to clients after every 30 days of the project. Clients only pay for the completed portion of the project. As project manager, you must determine the billing amounts throughout construction.

KEY POINTS

- Phase 4 begins where Phase 3 ends.
- Only manipulate cells D4 (dark blue) and D16 (dark orange) unless noted otherwise.
- Assume 7 day work weeks.

[Task a] The current fabrication schedule is based on a 10-hour work day per worker. To make up for lost time after an equipment breakdown, we have agreed to pay 2 hours overtime per day for each worker to work 12-hour days. What is the total duration for fabrication now? Manipulate cell E4 then fill the column to find the Fab Duration for each sequence. The Total Duration should be the sum for all of the sequences.

Seq. 1 Fab Duration using the original formula E4= C4*4/10/8
Fab Duration using the New formula E4 = C4*4/12/8
The total fabrication duration decreased from 42 to 35 days.

[Task b] If the fabrication drawings are delayed by a week, what is the new Fab Start day for Seq. 8? How could this change affect billing?

The new start date for Seq. 8 is day 39. Less of the project would be complete in the first 30-day billing period. Therefore, the client would be billed less money.

[Task c] Edit your tables to match the start dates you had for Phase 3c, keeping the accelerated fabrication time. We can bill the client every 30 days. Approximately what percent of fabrication will be complete? What percent of erection can we bill for?
Note: Sequences must be completely fabricated and erected before we can bill for it.

Sequences 1-6 will be fabricated in less than 30 days.
= (80 + 80 + 100 + 160+100 +160)/840 total pieces
= 680/840 ~ 81% of fabrication will be complete

Sequences 1and 2 will be erected in less than 30 days.
= (80 + 80)/840 ~19% of erection can be billed

[Task d] SteelFab charges clients $60/hour for fabrication. Calculate the amount the client must pay for fabrication based on Phase 4c above.

Sequences 1-6 will be fabricated in less than 30 days.
(3+3+4+7+4+7)days x 10hr/day x 8 workers x $60/hr = $134,400
(3+3+4+7+4+7)days x 2hr/day x 8 workers x $60/hr x 1.5OT= $40, 320 Bill total = $174, 720