INC 364 - 2021

Gurobi Optimization – Part 2

What have you learned last week?

- Spread workload between several production lines to meet the demand.
- Encountered with regular cost, over-time cost, weekend cost, inventory cost, and early production planning.
- However, those models had some limitations and might not be used in a practical environment.

What will you learn today?

To be more practical :

- The demand is a quantity to ship according to a list of customer orders.
- The cycle time of each material is different.
- Shortage cost is considered.

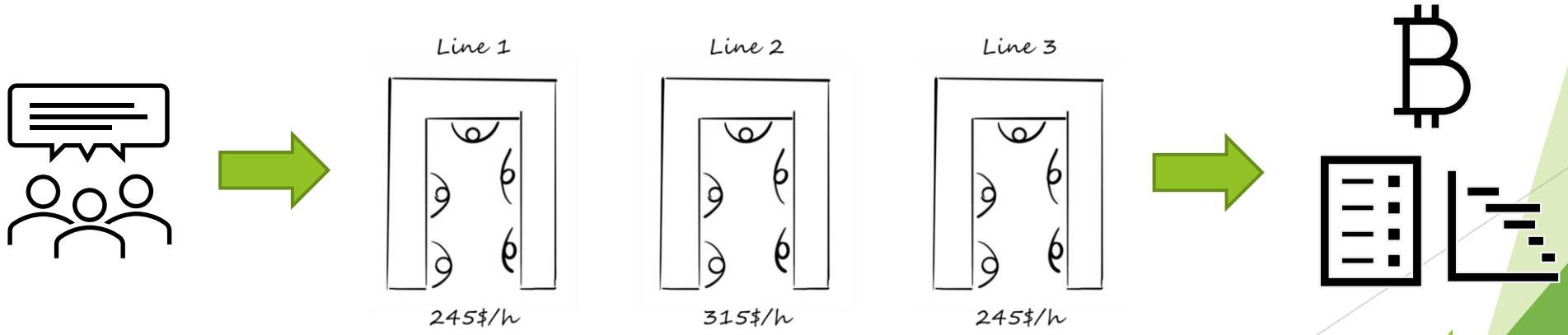
Final Output :

- Optimal Cost.
- Production Schedule – Time & Qty.
- Inventory & Shortage Plot.

Part 2 – Workshop Problem

We are in a make-to-order scheme with three production lines in parallel. The factory is organised so that one-piece flow is always respected and all the tasks to produce a material are realised on the same line. Between 7 and 12 hours per day, each production line can be initiated at an extra cost charged as overtime work.

We need to schedule the production orders to meet the requirement expressed by our list of customer orders.



https://towardsdatascience.com/optimization-of-a-weekly-production-plan-with-python-and-gurobi-part3-2d8da1d3fc4c

Part 2 – Customer Orders

Order	Product Family	Quantity	Delivery Date
A	Model_1	600	7/13/2020
B	Model_2	200	7/14/2020
C	Model_10	150	7/14/2020
D	Model_1	150	7/15/2020
E	Model_2	200	7/15/2020
F	Model_3	200	7/15/2020
G	Model_1	400	7/17/2020
H	Model_7	400	7/17/2020
I	Model_3	400	7/17/2020
J	Model_1	150	7/18/2020
K	Model_2	100	7/18/2020
L	Model_3	200	7/19/2020

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Part 2 – Line Capacity (8 Hr)

Line	Line 1	Line 2	Line 3
Model_1	320	350	320
Model_2	320	350	320
Model_3	300	350	320
Model_4	320	350	320
Model_5	320	350	320
Model_6	320	350	320
Model_7	320	350	320
Model_8	320	350	320
Model_9	320	350	320
Model_10	300	330	300
Model_11	300	330	300

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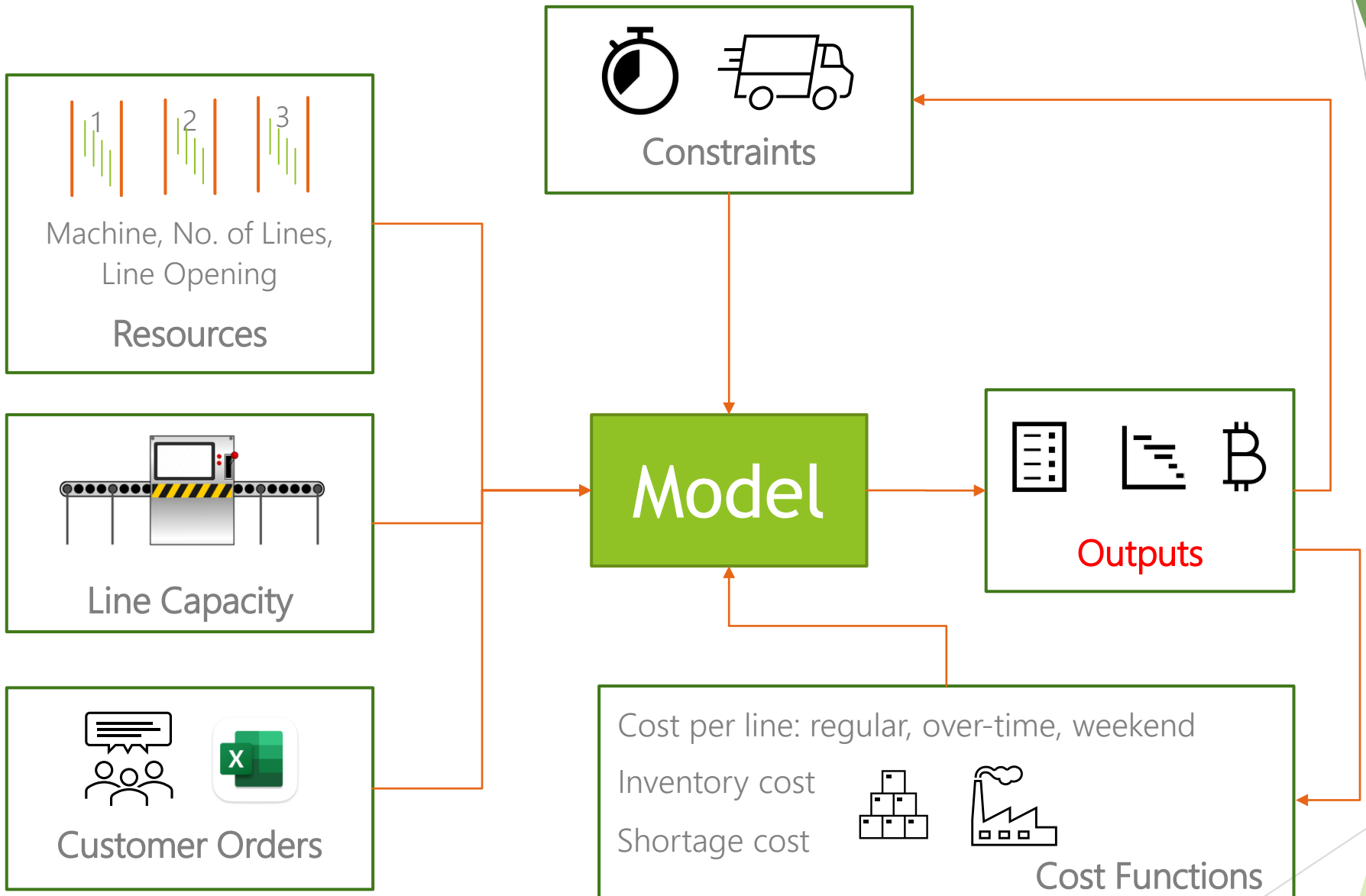

Constraints
1
2
3
Machine, No. of Lines, Line Opening
Resources
Model
Outputs
Line Capacity
Customer Orders
Cost per line: regular, over-time, weekend
Inventory cost
Shortage cost
Cost Functions

Part 2 – Things to Consider

- Line 1, 2, and 3 cost $245/hr, 315, and 245 respectively.
- If the line is opened, **minimum 7 hrs, maximum 12 hrs**.
- In **weekday**, if line works exceed 8 hrs, 50% of extra hours' cost needs to be paid.
- In **weekend**, working cost need to be paid twice.
- **Early production** is applicable, but the **inventory cost** is $5 per one-hour production per day.
- **Shortage cost** is $1,000 one-hour production per day.
- Each line has different capacity for each product. Also, each product has different cycle time.

Part 2 – Variable Definition

- x_qty(date, order, wc) = planned quantity of each customer order given date and work centre.
- x_time(date, order, wc) = planned time of each customer order given date and work centre.
- quantity(date, wc) = quantity to display in each date and work centre.
- line_opening(date, wc) = work centre open status in each date.
- reg_hours(date, wc) = regular working hours of each work centre given date.
- ot_hours(date, wc) = overtime working hours of each work centre given date.
- total_hours(date, wc) = total working hours on each work centre. It is the sum of regular and overtime working hours on the date the line is opened.

Part 2 – Variable Definition

- gap_prod(date, order) = gap for early/late production of each customer order given date.
- abs_gap_prod(date, order) = absolute value of gap production.
- early_prod(date, order) = early production
- inventory_costs(date, order) = inventory costs
- late_prod(date, order) = late production
- delay_costs(date, order) = delay cost (shortage cost)

Part 2 – Workshop Problem

Let' use Python & Gurobipy

To Solve the Problem

- customer_orders.xlsx
- line_capacity.xlsx
- Guropi_part2.ipynb

Part 2 – Tricky Formula

```
# Set the value of late production
model.addConstrs(
    (
        late_prod[(date, m)] == (abs_gap_prod[(date, m)] - gap_prod[(date, m)]) / 2
        for date in timeline
        for m in customer_orders
    ),
    name="late prod",
)
```

```
# Variable gap early/late production
gap_prod = model.addVars(
    timeline,
    customer_orders,
    lb=-10000,
    ub=10000,
    vtype=gurobipy.GRB.CONTINUOUS,
    name="gapProd",
```

Description: late_prod will only have value equals abs_gap_prod if gap_prod is negative

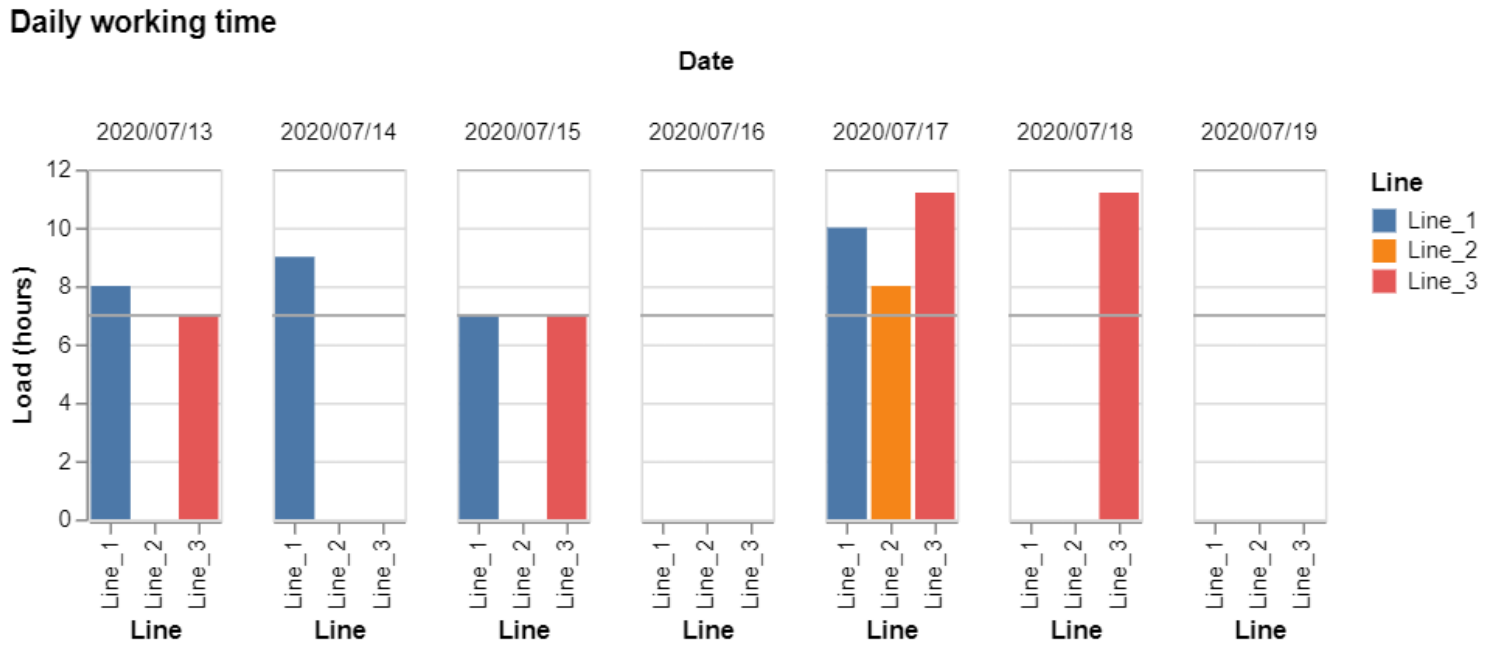
gap_prod
- early → "positive" → gap_prod == abs_gap_prod → late_prod = 0
- late → "negative" →

```
late_prod[(date, m)] == (abs_gap_prod[(date, m)] - gap_prod[(date, m)]) / 2
```

≡

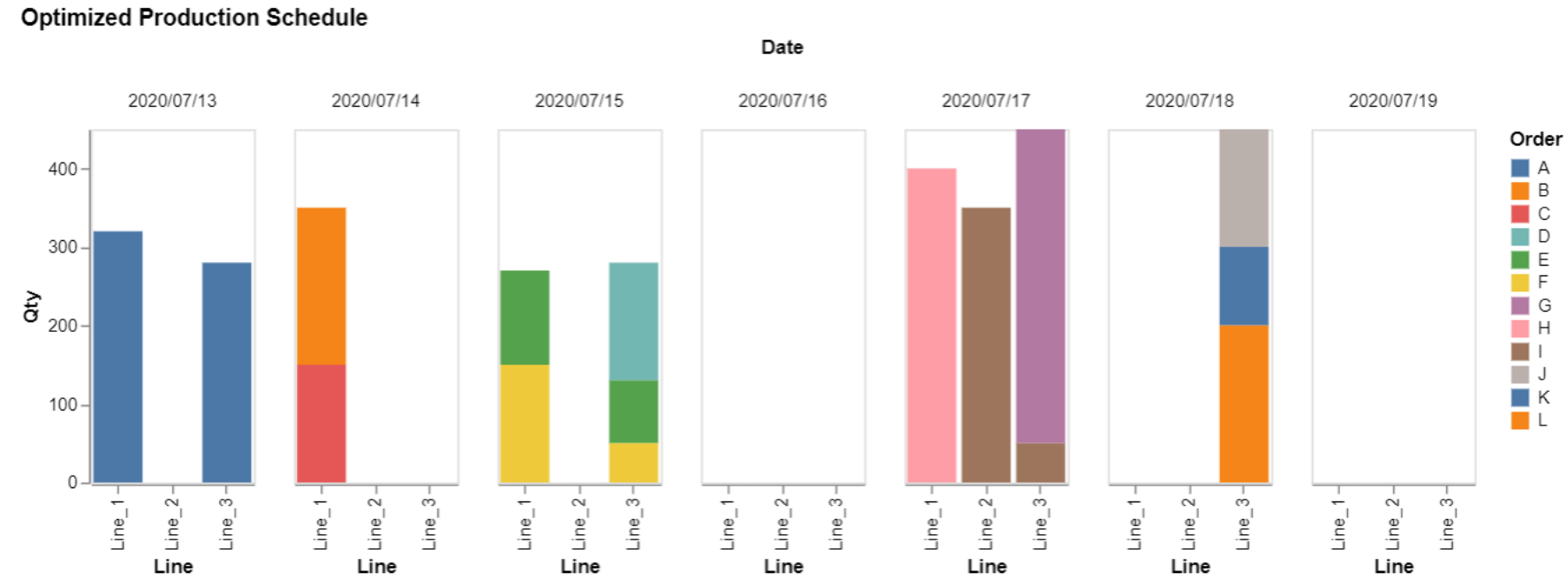
```
late_prod[(date, m)] == 2 * abs_gap_prod[(date, m)] / 2
```

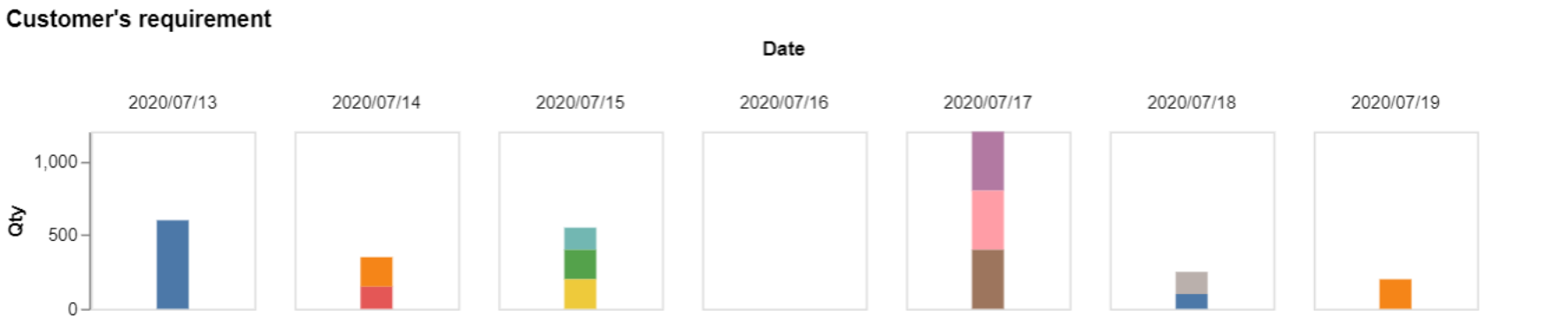
Part 2 – Workshop Problem



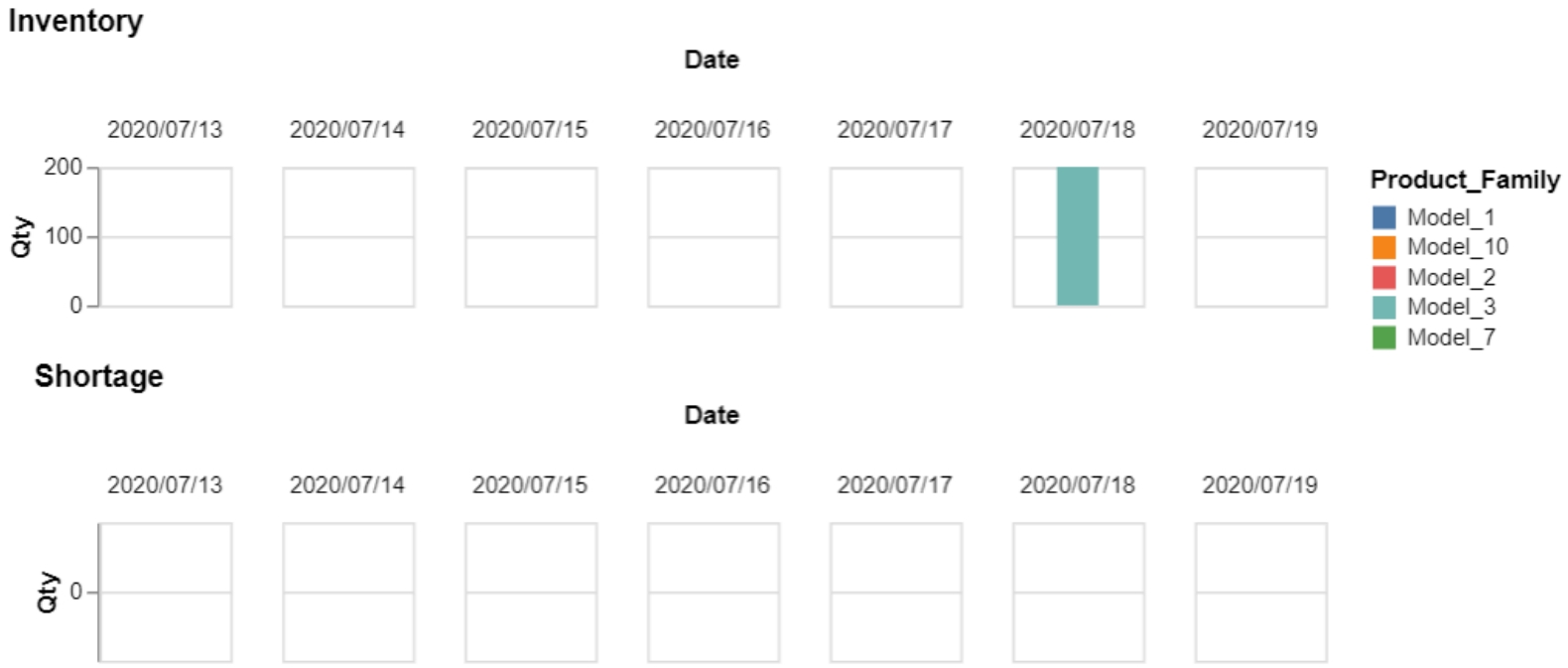

```
Explored 1 nodes (380 simplex iterations) in 0.24 seconds (0.03 work units)
Thread count was 8 (of 8 available processors)

Solution count 10: 24314.4 24314.4 24323.3 ... 34391.9

Optimal solution found (tolerance 1.00e-04)
Best objective 2.431437500000e+04, best bound 2.431437500000e+04, gap 0.0000%
Total cost = $24314.375
```

Part 2 – Workshop Problem





Part 2 – Workshop Problem



Assignment III

Assume that you are working in a Thai's well-known crude oil company. They ask you to develop a five-year operating plan for the gulf of Thailand which includes four offshore oil rigs in it. They are limited to operating a maximum of three rigs in this gulf each year. Even if a rig does not operate in a given year, the company is still required to pay royalties on it if there is a reasonable expectation that it will operate in the future. Otherwise, it may be permanently closed with no further royalties due.

Assignment III

The following table summarizes the annual royalties due on each active rig (whether operating or not):

Rig IDs	Royalties (Baht)
Rig A	13,085,600
Rig B	16,357,000
Rig C	13,085,600
Rig D	16,357,000

Assignment III

Each rig is limited to drilling a certain amount of crude oil per year and the quality of it (measured in API gravity) is different.

These restrictions include the following:

Rig IDs	Max Production (barrel)	API Gravity
Rig A	1.9 Million	21
Rig B	1.5 Million	30
Rig C	1.0 Million	45
Rig D	2.3 Million	15

Assignment III

Each year, the crude oil drilled from each operating rig must be combined to produce a specified grade of crude oil. The combined crude oil's annual requirements are as follows:

Year	Expected API Gravity
1	27
2	24
3	36
4	18
5	30

- The combined crude oil is sold at price 75 baht per barrel.
- Due to financial economic crisis, the company's revenue from crude oil sell is forecast to be discounted at the rate 5% per annum. The cost is assumed to be increased at the rate 2% per annum due to inflation.

You are assigned to give a plan according to the requirements that which rigs should be operated annually. How much crude oil should be drilled from each rig? How much the expected revenue gain from your plan?

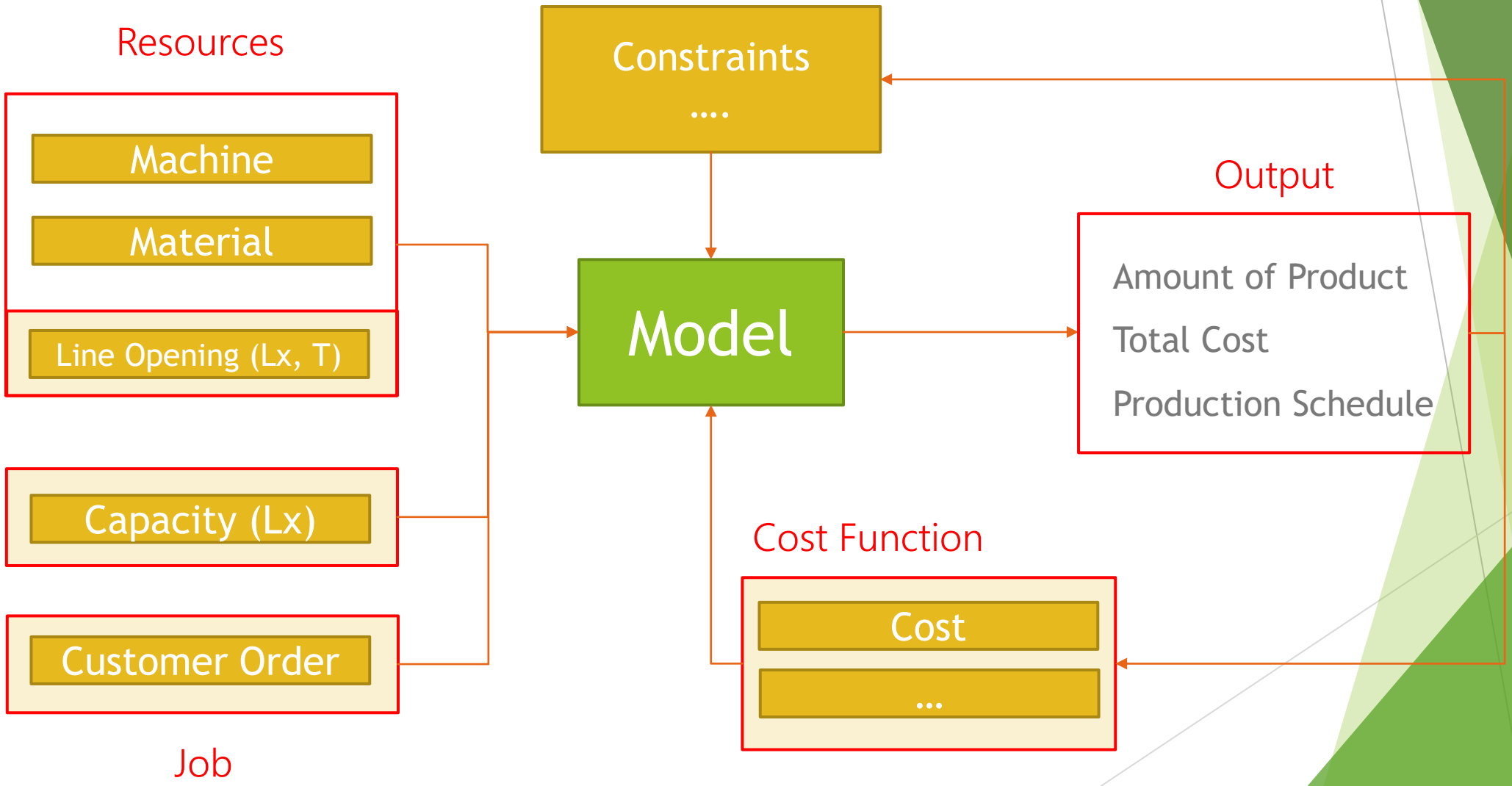
Assignment III

1. Identify the decision variables
2. Write down all constraints
3. State the objective function
4. Solve for optimisation solution using "**Gurobi with Python**".
5. Plot a planning result as bar graph like you have done in workshop.
6. Make a discussion on your result with your understanding.

** Submit as a PDF (code, result, graph, explanation, etc).

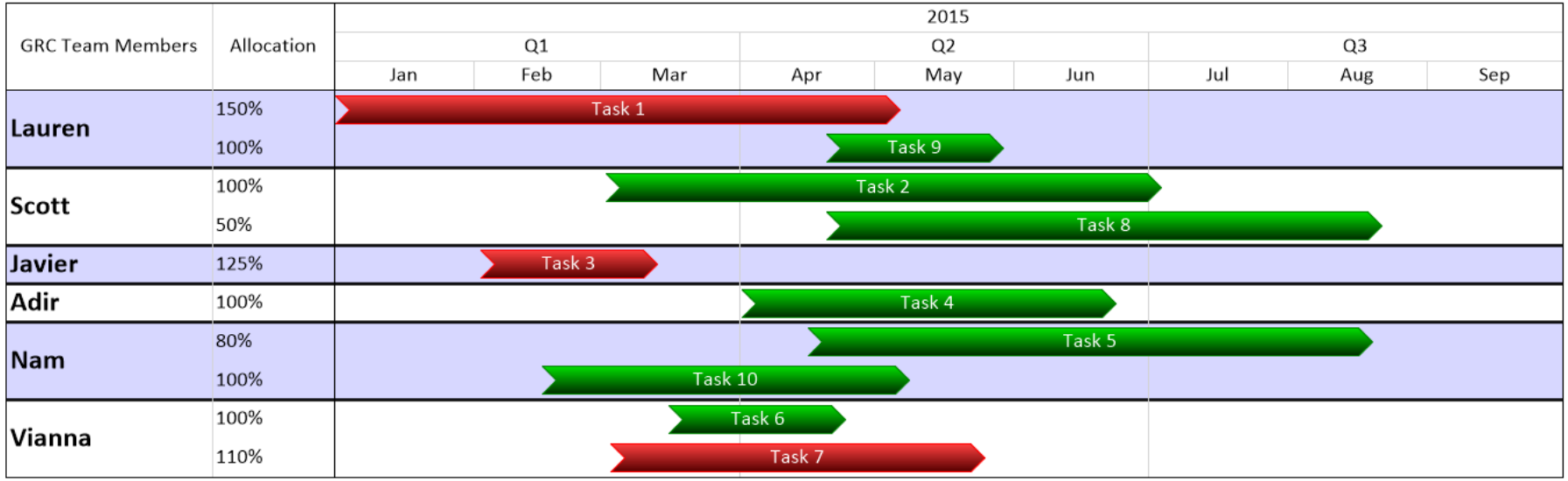
*** Don't forget to give a final answer.

Assignment III - Guideline



Assignment III - Guideline

GANTT CHART EXAMPLE



source: https://www.onepager.com/community/blog/showing-resource-allocation-in-a-gantt-chart/