CONTEST PROBLEM 11

IIE/RA Contest Problems

Eleventh Annual Contest: Rockland Steel Company

At Rockland Steel, we make steel coils that are ultimately used to form many common consumer products. One of our production facilities is a hot strip mill that turns steel slabs into coils of steel. The operation utilizes a transportation system that consists of a fleet of self-loading coil carriers, as well as a coil field inventory storage area. Unfortunately, our present system is causing frequent productivity problems and is preventing the pursuit of additional business. We are hiring you as a consultant to analyze our system and to suggest improvements.

Operation Details

Production

Our facility processes coils one order at a time. An order consists of up to 20 coils. All coils in an order are the same product and all are processed together sequentially. A coil looks similar to a very large roll of toilet tissue. Each coil may weigh between 5 and 25 megagrams (Mg), have a width of 100 to 190 centimeters, and have a strip length up to 600 meters.

Our steel is the raw material ultimately used for making items like car bodies and large appliances. Twelve different products account for the bulk of our production. Appendix 1 illustrates the parameters of each product and the percentage of the orders attributed to each. Figure 1 illustrates the layout of the facilities.

Hot Strip Mill (HSM)

A hot steel slab is run through a sequence of 10 rolling mills to reduce it to a long, thin strip of a specified width and thickness. That strip is fed into one of two coilers at the end of the mill where the coil is formed. The HSM can process coils at a rate of 400 Mg/hour. The coils are then removed by automated equipment (requires 0.3 minutes) and placed on a staging area associated with each coiler. While in that staging area, steel bands are applied to hold the laps of the coil together. The application of the bands requires 15-25 seconds per band. All coils require at least one band. Coils over 10 Mg require two bands; coils over 15 Mg require three bands. Each staging area can hold three coils.

After banding, the coil is moved by an overhead crane to a walking beam conveyor where it is staged for pickup. The walking beam conveyor is 30 meters long. It is a type of non-accumulating conveyor that automatically transfers the coils forward toward the delivery end. Coils can be placed anywhere on the conveyor and can be stored as close as five cm apart up to the full capacity of the conveyor. They are generally placed as close together as allowed.

The hot strip mill works continuously 24 hours per day, 7 days per week. As long as a coiler is available, a new slab will be started immediately after the preceding one is complete. If there is any delay waiting for a coiler, that is considered lost production. All incidents of lost production must be tracked and reported. In addition, we need reports of the total number and weight of coils produced. HSM production is considered complete when the coil is deposited in the storage field.

Each time a tractor picks up a coil, it causes damage that results in 0.5% yield loss. Good steel (after any yield loss) produced at the HSM contributes $150/Mg of added revenue.

Coil Transportation

We currently lease five tractors (coil carriers) designed specifically to allow self-loading, transportation, and unloading of coils. They are designed with large wide-set rubber tires that can straddle a material-handling or holding rack, and a ram that can reach inside one or more coils to pick them up. Each tractor has a weight capacity of 50 Mg and a ram capacity of 350 cm. They are capable of carrying multiple coils up to their weight capacity. They can actually carry a greater coil width than their ram length, but the total width of all coils cannot exceed the ram length by more than 50 cm. The tractors move at a speed of 80 m/min when loaded and 150 m/min when unloaded. When moving between the HSM and the cooling racks, safety policy restricts tractors to half their normal speed. Loading generally requires about 0.8 minutes and unloading requires about 0.5 minutes.

Our present operating policy is to dedicate each tractor to one of two functions:

- Function A: Two tractors move coils from the HSM to the cooling racks.
- Function B: Three tractors move coils from the cooling racks to inventory.

Additional tractors could be leased, if necessary. Annual lease and operating cost is $1,250,000 per tractor.

Inventory Coil Storage Field

There are 10 regions in a field where coils are kept. The lower numbered regions are closer, and hence more desirable; but for that reason, they are also often full. An entire order is always stored together in the same region. An order has a 30% chance of being stored in the first region, a 20% chance of being stored in the second region, and a 15% chance of being stored in the third region. If not stored in one of the first three regions, an order then has an equal probability of being stored in any region beyond the third.

The regions are laid out in a roughly linear fashion. The distance between regions is specified in Appendix 2. After a tractor arrives at a region entry, the travel time within the region to the actual storage location is 0.5 to 1.5 minutes each way. For the purposes of this study, additional inventory details are not relevant. It is not necessary to keep track of specific coils in inventory or the space available in each region.

Cooling Requirements

Obviously, when coils come off the HSM, they are still very hot. If coils are moved into the storage field too quickly, they can warp or flatten because there is no support of the

coil shape. We have a set of cooling racks that help maintain the shape of the coil until it is cool enough to hold its shape without support. A minimum time of 1.4 minutes per Mg of coil weight must elapse from the time a coil exits the coiler until it is deposited into the inventory storage field. In other words, a coil cannot be placed in the coil yard without first having spent at least this much time on the HSM conveyors, the cooling racks, or the tractor itself. There are only 100 meters of cooling racks, so the coils cannot be stored there indefinitely. Any coils placed there must eventually be moved to the storage field before the cooling racks are full.

Measures of Effectiveness

Our primary measures of effectiveness are:

- HSM Productivity (Mg/week)
- Overall Operating Profit ($/week)

Secondary measures include:

- HSM Downtime
- HSM Yield Loss
- Transportation Cost

Project Objectives

Bottom-line Improvement

What changes to our facility or operating rules do you recommend to allow us to improve our productivity, reduce costs, or in general, improve our operating profit?

Tractor Enhancement

We are considering leasing different tractors with an extended ram option. We can extend the ram length to 450 cm, potentially allowing the tractors to carry more wide coils but with the same weight limitation. The downside is that the loaded speed of the larger-ram tractors is limited to 65 m/min, and it will add an extra $100,000 per tractor to the annual operating cost. Is this option desirable?

Yield Improvement

Yield is the percentage of good product after any scrap loss. We have found that adding an additional four minutes to the minimum cooling time can reduce the tractor-handling yield loss to 0.4%. Could this change to our handling policy improve our productivity? Does it require any other changes?

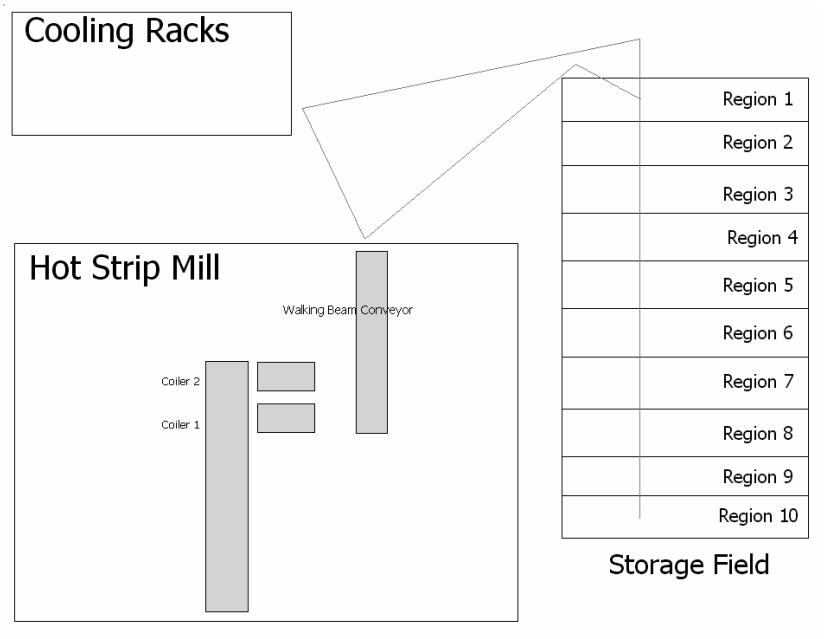

Figure 1 – Facility Layout

Appendix 1 – Product Mix

Product	Weight/Coil (Mg)	Width/Coil (cm)	Strip Length/Coil (m)	Percent of Orders
1	5	100	250	9
2	12	110	500	9
3	13	100	600	7
4	12	125	450	6
5	11	130	400	11
6	17	130	600	8
7	8	155	250	4
8	14	155	400	7
9	19	175	500	11
10	22	180	550	7
11	10	190	250	12
12	25	190	600	9

Number of Coils per Order	Hot Strip Mill (by percent)
1	0
2	0
3	0
4	0
5	33
6	0
7	0
8	0
9	0
10	22
11	0
12	0
13	0
14	0
15	18
16	0
17	0
18	0
19	0
20	27

Appendix 2 – Distance Between Areas

From	To	Distance (m)
Hot Strip Mill	Cooling Racks	150
Hot Strip Mill	Region 1	400
Cooling Racks	Region 1	450
Region 1	Region 2	100
Region 2	Region 3	100
Region 3	Region 4	100
Region 4	Region 5	100
Region 5	Region 6	100
Region 6	Region 7	100
Region 7	Region 8	100
Region 8	Region 9	100
Region 9	Region 10	100