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Guidebook for Railway-themed K-12 STEM Outreach Activities

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Introduction

Welcome to the *Guidebook for Railway-themed K-12 STEM Outreach Activities*! Inside, you will find descriptions of educational activities designed to introduce students to the railroad transportation mode through the lens of STEM (Science, Technology, Engineering, and Mathematics) concepts.

Railroads have been a critical part of the global economy since the 1830s. Today, railroads haul more ton-miles of intercity freight (one ton of freight moved one mile) than any other mode of transportation in the United States. While the railroad industry is the leader in long-haul freight transportation, recruiting students to leadership roles in the industry is challenging. With many railroad employees approaching retirement age, the need to raise student awareness of railway industry career opportunities has never been greater.

The activities in this guidebook cover a wide variety of railroad topics. The activities are intended to be hands-on to provide students with knowledge through experiential learning that also increases their awareness of railway transportation technology. Although the following chapters provide a step-by-step guide to each activity, we encourage you to experiment with modifications to each activity and to create your own activities on other facets of the railroad industry and STEM topics.

We hope you find the activities in this guidebook to be informative and entertaining!

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Classification Yards and Railcar Sorting

Railway yards sort cars into groups based on destination. This activity demonstrates several methods used to sort the cars.

Number of Participants: 1-12 **Recommended Age:** 12+

Setup Time: 5 minutes **Activity Time:** 20 minutes

STEM Concepts:

- *Engineering: flat classification yards become inefficient with large volumes of railcar traffic*
- *Mathematics: matrices can be used to track railcar movements in a classification yard*

Key Learning Points

1. **Classification yards are locations where railcars arriving on inbound trains are uncoupled, sorted by destination, and assembled into new outbound trains.**
2. **Different types of classification methods are used depending on traffic and available infrastructure.**

Background

Railroads are a complex network of main lines, branch lines, local yards, and classification yards that connect thousands of origins and destinations for freight traffic. Unlike trucks that carry a single shipment directly from shipper to receiver, railroads gather dozens of railcars carrying individual freight shipments into a train. Simultaneously transporting multiple freight shipments in a single train allows railroads to be the most energy efficient mode of land transportation.

Some railway customers want to ship an entire trainload of freight at once. These trains can move directly from origin to destination such as those transporting coal from a min to a power plant. However, many customers want to ship a smaller number of railcars at a time, or they want to ship a larger number of railcars to many different destinations at the same time. To move these railcars efficiently, railroads operate a complex network of freight trains that transport railcars between intermediate staging points known as classification yards.

Classification yards are central to the freight railroad network, sorting thousands of freight cars each day into “blocks” (groups of cars heading in the same direction or to the same destination) and ultimately into trains that move them closer to their destinations. A typical classification yard will have many parallel tracks used to sort and store blocks of railcars until they are ready to depart on a train. While some classification yards use gravity to sort the railcars (known as hump yards), others are “flat switching” yards where railcars are sorted by a switching locomotive. Several different sorting methods can be used depending on the available yard track infrastructure and number of possible destinations for the railcars. This activity helps participants familiarize themselves with three of these sorting methods (basic, matrix, and triangular).

Figure 1: A railroad "ladder", a series of turnouts leading to a group of yard track

Figure 2: Classification tracks at a hump classification yard

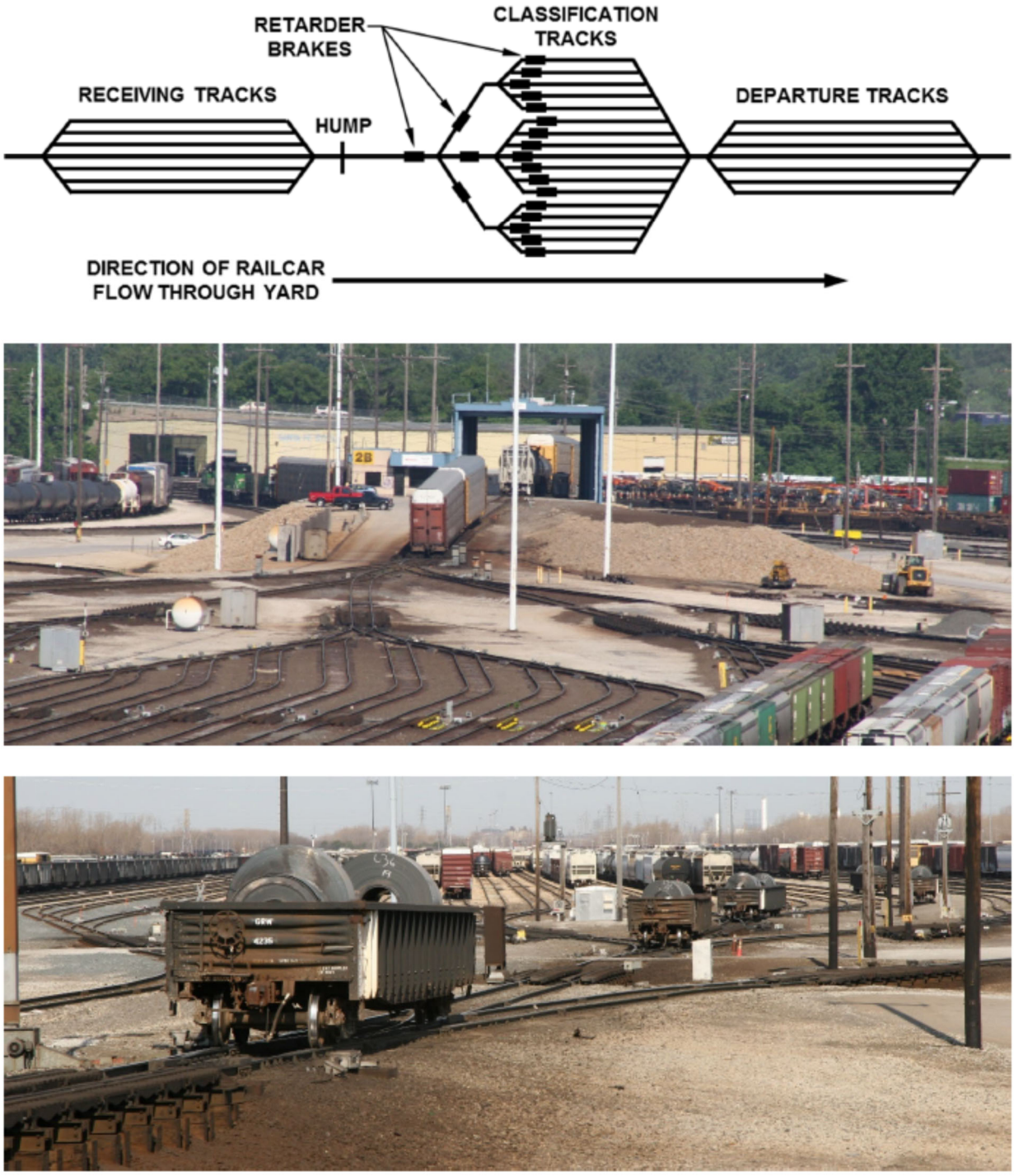

Figure 3: A hump at a classification yard

Figure 4: A switching locomotive at a flat switching yard

Materials List and Setup

For this activity, there are several options for materials to create a simple yard layout for demonstrating different railcar sorting strategies to form blocks in a classification yard:

- BRIO-style wooden track with compatible trains (preferred)
- Tape (for track) and cardboard cutouts (of trains)
- Scale model trains with EZ-track sections

Regardless of material choice, all setups will require 18 railcars to replicate the activity as described. A locomotive is not required but can help illustrate the movements required to switch railcars between the different tracks in the yard.

The remainder of this description assumes the activity will use BRIO-style track with compatible wooden trains. Most of the track and train materials listed below can be ordered through online retailers but can often be found at local toy stores that specialize in wooden and/or imported educational toys.

Yard Track Setup:

At a minimum, a yard layout with three parallel tracks is required to demonstrate all three railcar sorting strategies. For a BRIO setup using three yard tracks, the following track sections are required:

- 30 x D (8.5" straight tracks)
- 8 x L or M (turnouts)
- 2 x E (6.5" curves)
- 1 x Locomotive
- 18 x Railcars

Figure 5 illustrates a three-track yard setup using BRIO track. Other track materials should follow a similar pattern. It is critical that the single track at left, referred to as the "switching lead track", is long enough to hold all 18 railcars at once. Each of the parallel yard tracks at right, referred to as the "classification tracks" must be long enough to hold six railcars.

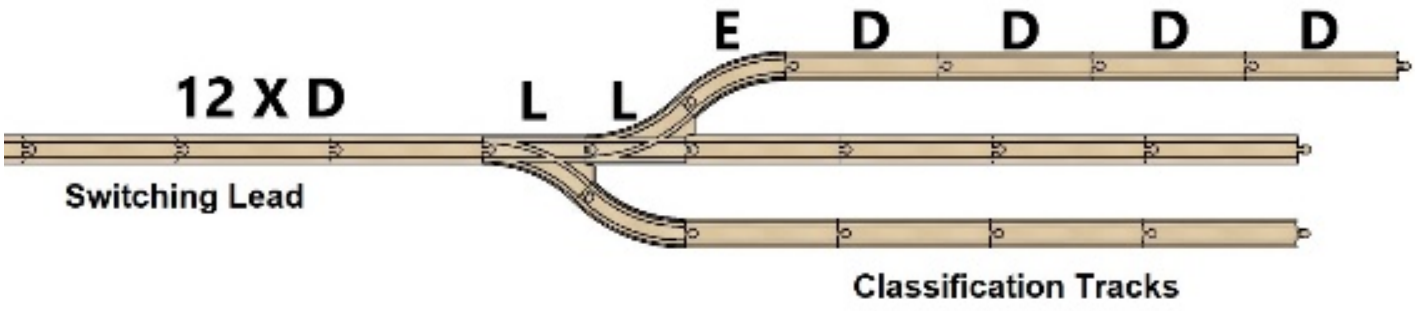

Figure 5: Three-track yard using BRIO track

Additionally, if there are sufficient track materials available, the yard may be set up with nine tracks for the basic sorting portion of the activity as shown in Figure 6.

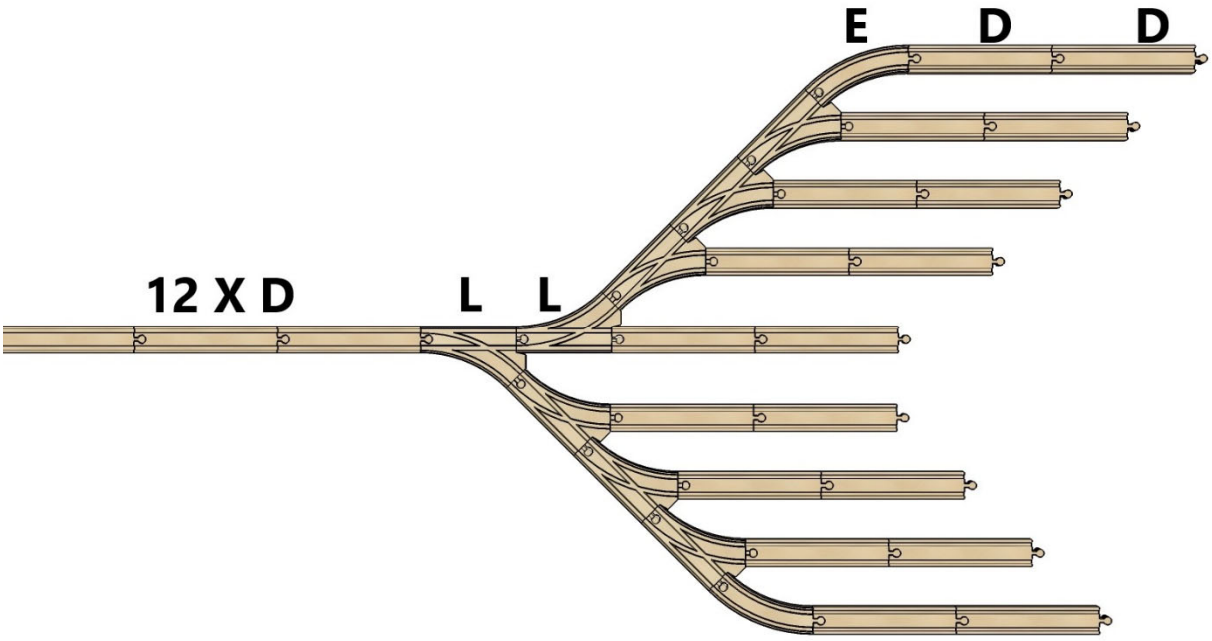

Figure 6: Nine-track yard using BRIO track

*Use of adapter (C2) is recommended if buying new track since turnouts come in pairs of L and M

Railcar Setup:

To help the students keep track of the block assigned to each railcar, affix a tape or sticky label to the top of each railcar with its block assignment written on it in marker.

If you only have enough materials to form a three-track yard, two of the 18 railcars should be assigned to each of the following blocks and labelled accordingly: 1-A, 2-A, 3-A, 4-B, 5-B, 6-B, 7-C, 8-C, 9-C.

If you have enough material to construct a nine-track yard, two of the 18 railcars should be assigned to each of the nine blocks ad labelled accordingly: 1, 2, 3, 4, 5, 6, 7, 8, 9.

Activity Script

This activity will cover three different rail sorting strategies used to form blocks in classification yards: basic, matrix and triangular sorting.

Before proceeding to the sorting strategies, if using wooden or scale model tracks, you may want to have the students assemble the three-track or nine-track yard layout based on a sketch or the diagrams provided earlier. This will allow the students to learn how the turnouts and track sections fit together to form the overall yard layout.

Stage 1: Basic Sorting

1. Assemble the three-track or nine-track yard.
2. Place all 18 railcars on the switching lead track in random order. Make sure the block assignments are sufficiently scrambled. If using wooden BRIO-style trains, make sure the magnetic polarity of each railcar is in the correct orientation. The optional locomotive should be placed at the far end of the string of railcars, away from the classification tracks.
3. Basic sorting is the simplest and most common method to sort cars into new blocks. Figure 7 below shows basic sorting of 18 cars into 3 blocks.

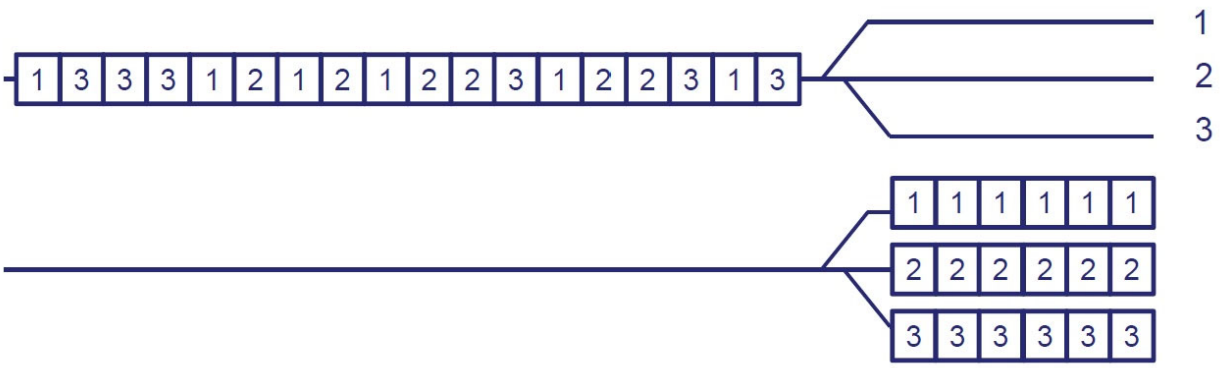

Figure 7: Basic sorting

4. Manually push and pull the railcars into each track based on their assigned blocks using the figure above as a guide.
    a. If using a three-track yard, place all cars with "A" in their labels on track 1, "B' on track 2, and "C" on track 3 to form three blocks.
    b. If using a nine-track yard, place cars labelled "1" on track 1, "2" on track 2 etc.
5. Discuss the advantages and disadvantages of this strategy with the students. Some of these may not become apparent until after the other strategies are demonstrated.
    a. Basic sorting advantages: cars are only handled once, each block on a dedicated track
    b. Basic sorting disadvantages: relatively large number of tracks to produce same number of blocks as other methods
6. To prompt the students to think of alternative sorting strategies, ask them how they might handle either of the following situations:
    a. For the three-track yard, how can you make more than three blocks on three tracks?
    b. For the nine-track yard, how can you still make nine blocks using fewer tracks?

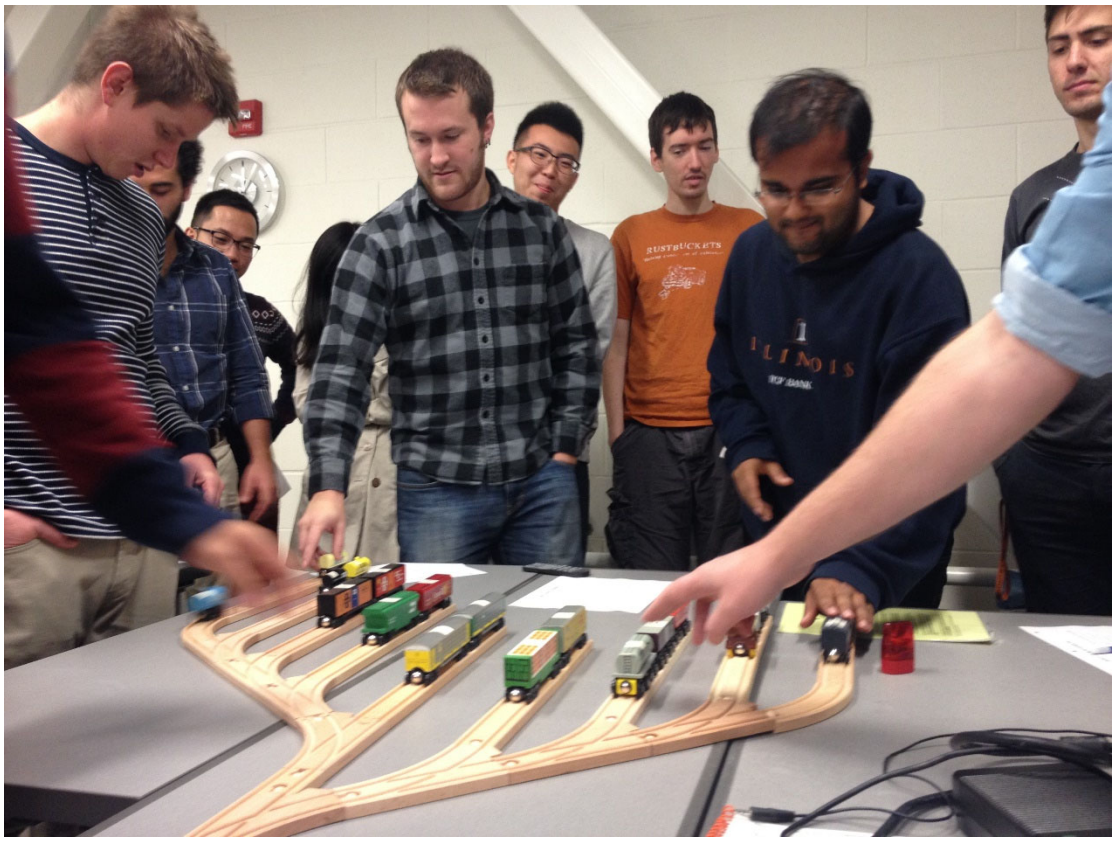

Figure 8: Sorting railcars into nine blocks on nine tracks.

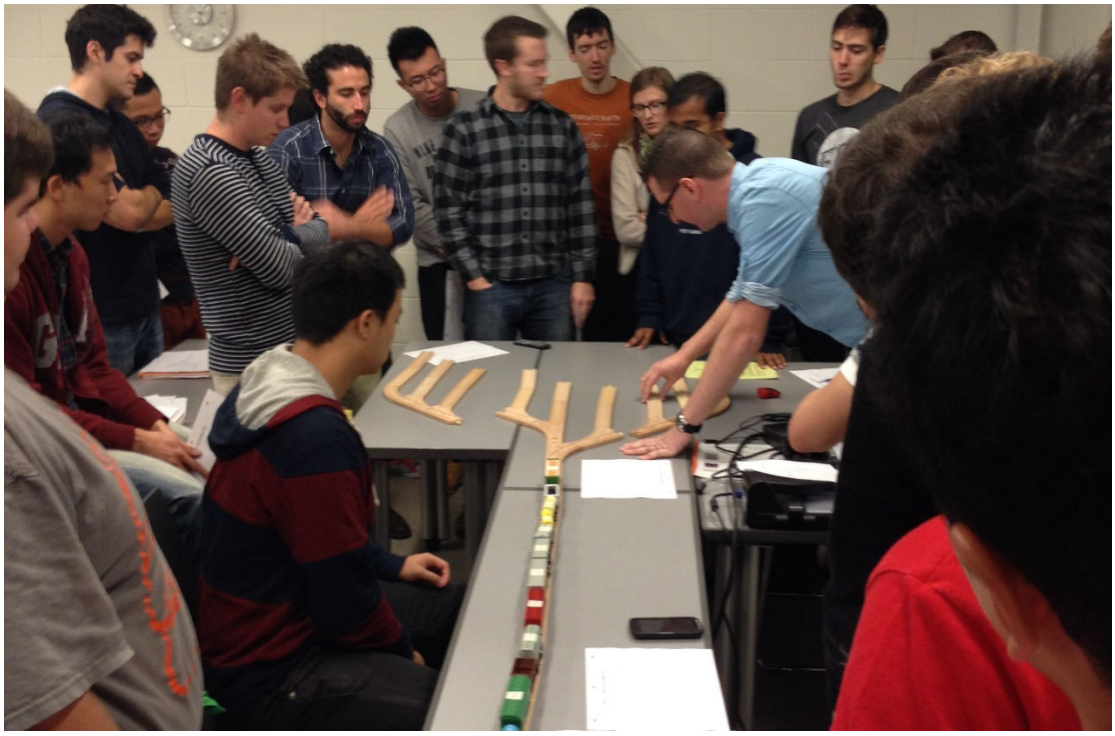

Figure 9: Removing six of the nine tracks for the challenge of forming nine blocks on three tracks.

Stage 2: Matrix Sorting

1. If a nine-track yard was used for Basic Sorting (Stage 1), remove six of the yard tracks (three from either side) to form a three-track yard (Figure 5). If a three-track yard was used for basic sorting, continue with the same layout.
2. Place all 18 railcars on the switching lead track in random order as done for Stage 1 (it does not need to be the exact same order).
3. Since there are only three tracks, there not enough tracks to form nine blocks independently using basic sorting. The railcars must be sorted multiple times using a multi-stage sorting technique called Matrix Sorting.
4. In the first stage (shown in Figure 10), the cars are sorted into groups of three blocks, although cars in the same block will not necessarily be adjacent to one another after the first sort. Using the figure as a guide, manually push and pull the railcars labelled 7, 4 and 1 into Track 1; 8, 5 and 2 into Track 2; and 9, 6 and 3 into Track 3.

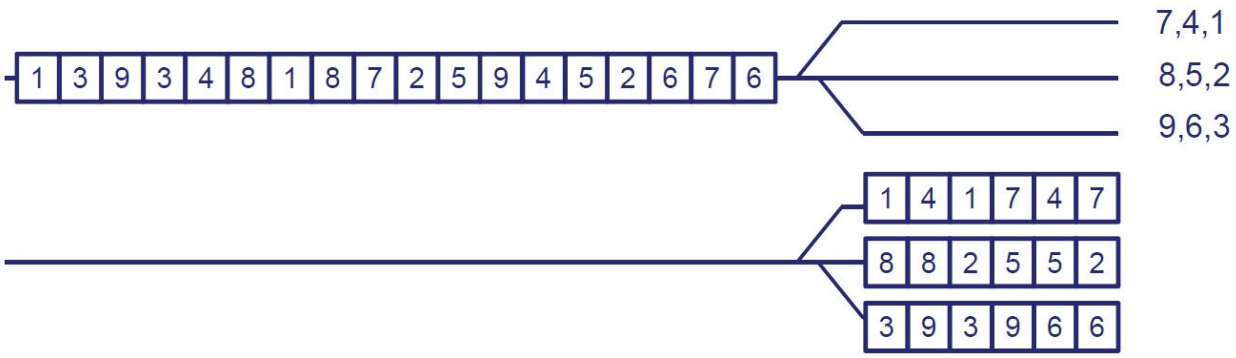

Figure 10: Matrix sorting stage 1

5. Pull the railcars from Track 3 back to the switching lead track, followed by the railcars from Track 2 and then the railcars from Track 1. Note that in an actual yard operation, the following moves must be made:
    a. The locomotive couples to the railcars on Track 1,
    b. The locomotive pulls the Track 1 railcars back to the lead, and then push them forward to couple on to the cars from Track 2.
    c. The locomotive pulls the Track 1 and Track 2 railcars back to the lead.
    d. The locomotive pushes the Track 1 and Track 2 railcars forward to couple to the railcars from Track 3.
    e. The final move involves pulling all 18 railcars back to the switching lead track.
6. Ask the students to inspect the order of the railcars on the switching lead track. Do they notice anything that might help them sort the railcars into blocks?
    a. Note that each third of the train is only composed of railcars from three different blocks.
    b. This pattern allows basic sorting to be used on each third of the train to form three separate blocks in succession on each yard track.

7. During the second stage (Figure 11), the cars will be correctly blocked with three blocks "stacked" on each yard track. Using the figure as a guide, manually push and pull the railcars labelled 1 into Track 1, 4 into Track 2, and 7 Track 3 for the first third of the train, followed by 2 into Track 1, 5 into Track 2, and 8 Track 3 for the middle third of the train, and finally 3 into Track 1, 6 into Track 2, and 9 Track 3 for the final third of the train.

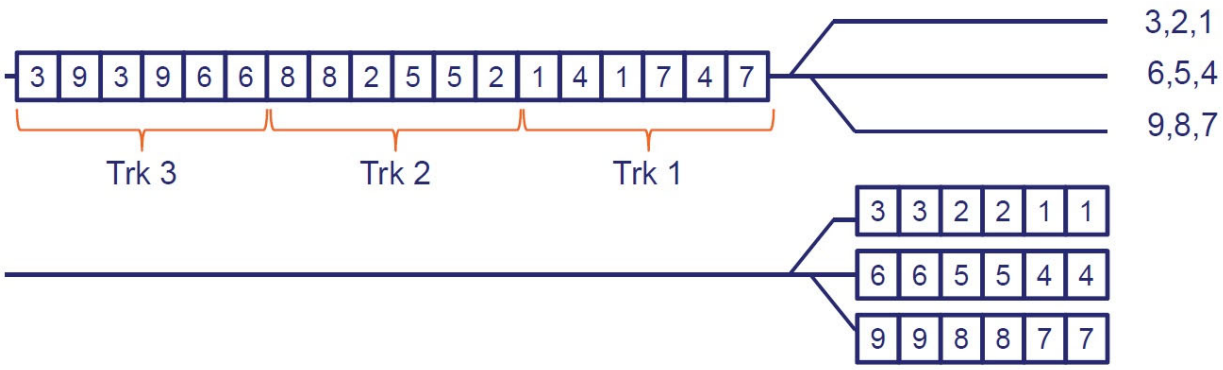

Figure 11: Matrix sorting stage 2

8. Discuss the advantages and disadvantages of this strategy with the students. Some of these may not become apparent until after the other strategies are demonstrated.
    a. Matrix sorting advantages: can create more blocks than there are tracks available (if there are n yard tracks, one can create n^2 blocks)
    b. Matrix sorting disadvantages: railcars are handled twice, more horsepower required to pull all cars at once during the final move to setup the second stage sort (i.e. when Tracks 1 , 2 and 3 are all pulled back to the switching lead).
9. To prompt the students to think of alternative sorting strategies, ask them how they might handle either of the following situations:
    a. Is there a way to sort railcars without pulling all of the tracks back at the same time?
    b. If only six blocks are made, does this open up additional possible strategies?

Stage 3: Triangular or Geometric Sorting

1. Continue using the same six-track yard used for Matrix Sorting.
2. Select 12 of the 18 railcars, either those labelled blocks 1 through 6 or blocks 1-A through 6-B, and place them on the switching lead track in random order. The cars labelled for blocks 7-9 and 7-C to 9-C can be set aside.
3. Since there are only three tracks, there not enough tracks to form six blocks independently using basic sorting. The railcars must be sorted multiple times using a multi-stage sorting technique called Triangular Sorting (also known as Geometric Sorting).
4. Triangular sorting takes place in three stages.
5. In the first stage (shown in Figure 12), the cars are sorted into three groups of blocks, one on each track. Cars in the same block will not necessarily be adjacent to one another after the first sort. Using the figure as a guide, manually push and pull the railcars labelled 1 into Track 1; 4 and 2 into Track 2; and 6, 5 and 3 into Track 3.

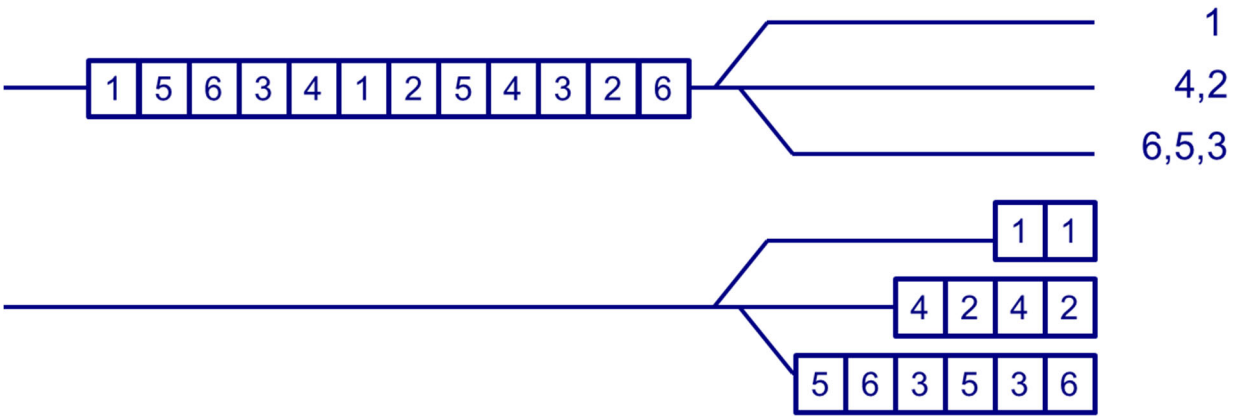

Figure 12: Triangular sorting stage 1

6. Ask the students if any blocks have been formed in the yard after the first sort.
    a. Note that the railcars in Block 1 are already sorted together on Track 1.
7. Pull the railcars from Track 2 back to the switching lead track.
8. Ask the students to inspect the order of the railcars on the switching lead track. Do they notice anything that might help them sort the railcars into blocks?
    a. Note that only cars for blocks 2 and 4 are on the lead track.
9. In the second stage (shown in Figure 13), the cars on the lead are sorted into two blocks: one on Track 2 and one on Track 1 "stacked" on top of Block 1. Using the figure as a guide, manually push and pull the railcars labelled 4 into Track 1, and 2 into Track 2.

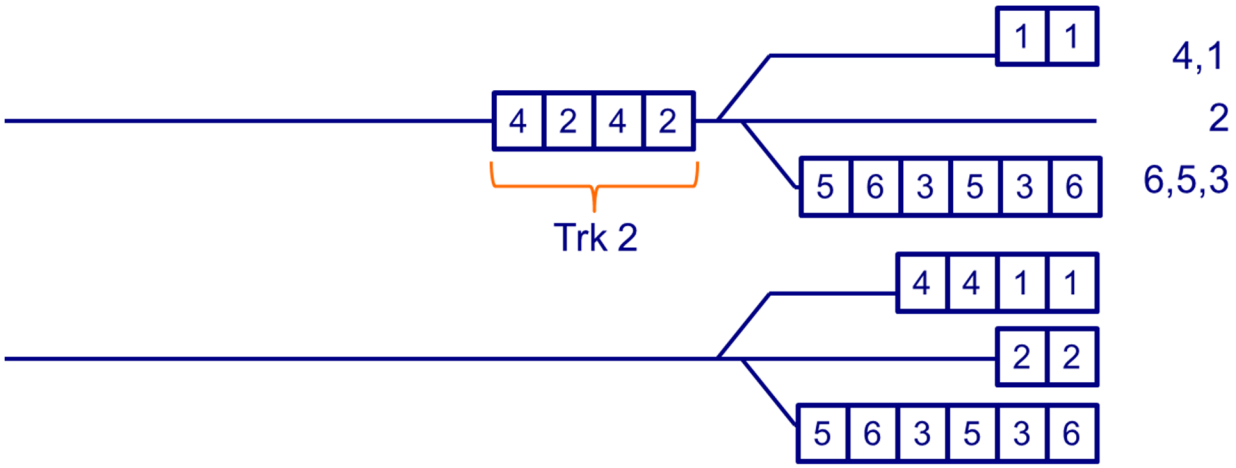

Figure 13: Triangular sorting stage 2

10. Ask the students if any blocks have been formed in the yard after the second sort.
    a. Note that the railcars in Block 2 are now sorted together on Track 2.
    b. Blocks 1 and 4 are sorted on Track 1 (but stacked).
11. Pull the railcars from Track 3 back to the switching lead track.

12. Ask the students to inspect the order of the railcars on the switching lead track. Do they notice anything that might help them sort the railcars into blocks?
    c. Note that only cars for blocks 3, 5 and 6 are on the lead track.
13. In the third stage (shown in Figure 14), the cars on the lead are sorted into three blocks: one on Track 3, one on Track 2 "stacked" on Blocks 2, and one on Track 1 "stacked" on top of Blocks 4 and 1. Using the figure as a guide, manually push and pull the railcars labelled 6 into Track 1, 5 into Track 2 and 3 into Track 3.

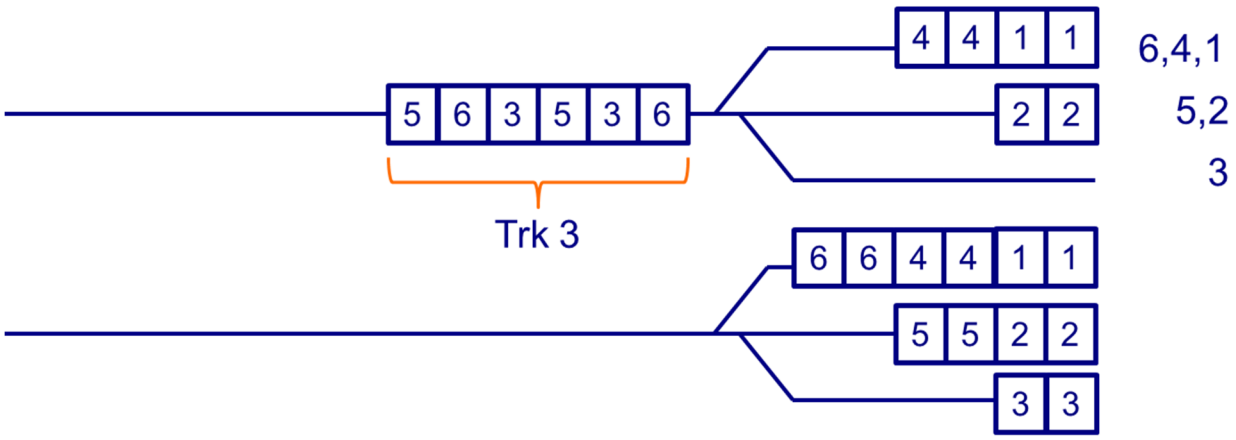

Figure 14: Triangular sorting stage 3

14. Note that all of the railcars have been sorted into six blocks.
    a. Blocks 6, 4 and 1 are stacked on Track 1.
    b. Blocks 5 and 2 are stacked on Track 2.
    c. Blocks 3 is alone on Track 3.
15. Discuss the advantages and disadvantages of this strategy with the students. Some of these may not become apparent until after the other strategies are demonstrated.
    a. Triangular sorting advantages: uses fewer tracks than basic sorting to create the same number of blocks, only one track is pulled at a time.
    b. Triangular sorting disadvantages: cars can be handled multiple times, all cars must be in the yard before the second and third stage sorts begin.

Questions to Stimulate Student Thought

1. Why do railroads care about how fast a classification yard can sort cars?
2. How can railroads increase the number of cars a yard can sort over a given time period?
3. Would the sorting methods discussed in this activity be more useful in a flat switching yard or a hump yard?
4. To demonstrate the n^2 blocks property of Matrix Sorting, show how four tracks can be used to form 16 blocks and five tracks used to form 25 blocks using this strategy.
5. How many tracks are required to sort the original nine blocks using Triangular Sorting?

Adjusting for Participant Time and Age

1. For younger participants or to shorten the activity, try eliminating one of the methods discussed above. Basic sorting can be skipped if time does not allow, or either triangular or matrix sorting could be skipped for younger groups.
2. To expand the activity, try increasing the number of cars or tracks available for sorting. Discussion of the questions in the previous section can also lead to some insightful discussions about the role of rail yards in overall rail network capacity.
3. As described previously, have the students assemble the yard layout at the start of the activity to become more familiar with how turnouts and track sections are used to form a yard.

The following paper is an excellent resource for more information about multistage soring techniques:

Daganzo, C.F., R.G. Dowling, and R. W. Hall. Railroad classification yard throughput: The case of multistage triangular sorting. *Transportation Research Part A: General,* Vol. 17, 2, 1983, pp. 95-106. DOI: https://doi.org/10.1016/0191-2607(83)90063-8