SUBCOURSE TR0603

EDITION 3

RAIL OPERATIONS PLANNING

AIPD

READINESS/ PROFESSIONALISM THRU GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

CORRESPONDENCE COURSE OF THE

U. S. ARMY

TRANSPORTATION SCHOOL

RAIL OPERATIONS PLANNING

EDITION 3

15 CREDIT HOURS

LESSON EXERCISES

TRANS SUBCOURSE 603

Fort Eustis, Virginia

Supersedes Trans 603, Rail Operations Planning, August 1970.

*****IMPORTANT NOTICE*****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

TRANS SUBCOURSE 603

RAIL OPERATIONS PLANNING

INTRODUCTION

Two world wars, the Korean war, and the Vietnam conflict have brought into sharp focus the tremendous demands of global warfare on transportation of all kinds. Despite lack of time, adverse weather, and enemy opposition, the Army must always have adequate transportation immediately available for use anywhere in the world. Not only is it necessary to move men and equipment to danger spots wherever they may be located, but it is also necessary to keep them constantly supplied with all the stores and equipment the situation requires. The planning for such operations is a tremendous task.

When it becomes desirable to use a railroad located in a theater of operations, planning is especially difficult. The condition of the railroad and the capability of its equipment may be unknown; without constant maintenance, weather alone can cause rapid deterioration. Add war-inflicted damage and it is clear that the job of reestablishing operations will not be easy. Enemy bombers and saboteurs can further complicate matters. A single-track railroad through rugged territory or through an area where the people are hostile to U. S. forces can prove particularly difficult to operate and maintain. Nevertheless, a plan must be made for the operation.

It may be your job to appraise a rail line and to plan for its use. After studying the reference text to this subcourse, you are expected to be able to explain how and where intelligence data are obtained on a railroad network and to determine the capacity of the rail line, how Much of what kind of equipment is needed, the number and kind of operating personnel required, and the amount and kind of supplies needed to support the rail operation.

The subcourse consists of four lessons and an examination as follows:

			Credit hours
Lesson	1,	Tonnage Capacity Determination	2
	2,	Tonnage Capacity Determination (continued)	4
	3,	Equipment and Personnel Requirements	3
	4,	Supply Requirements	2
Examination			4
		Total	15

Texts and materials furnished: Reference Text 603, Rail Operations Planning, December 1973, with Annex A.

Upon completion of this subcourse, you keep the reference text and all lesson assignment sheets; do not return them with your answer sheet.

LESSON 1..........................Tonnage Capacity Determination.

CREDIT HOURS.......................2.

TEXT ASSIGNMENT....................Reference Text 603, paragraphs 1.1-2.5.

MATERIALS REQUIRED.................None.

LESSON OBJECTIVE...................To enable you to list responsibilities involved in planning a rail operation, to identify a locomotive by its wheel arrangement, and to figure tractive effort and drawbar pull.

SUGGESTIONS

When making calculations, follow the sequence set forth in the examples in Reference Text 603. Raise any fraction encountered to the next higher whole number.

EXERCISES

Weight True-False

(Mark next to the item a "T" for true and an "F" for false.)

2 1. Planning for a rail operation begins when military forces enter a theater of operations.

Weight

2 2. A railway planner finds details on maps and photographs of great value.

2 3. If required data are not available, a planner uses assumptions gained from experience gained in past operations.

2 4. Details on right-of-way, roadbed, and track are not required in early planning.

Cluster True-False

(Each of the following groups of questions is related to the stem that immediately precedes the group. Identify each item as true or false in relation to that statement.)

FIRST GROUP

In connection with gathering, processing, and maintaining railway intelligence data, and the responsibility for rail planning, you realize that:

4 5. Much of the destruction of captured enemy railroads in a theater is caused by the enemy themselves.

4 6. The staff and planning functions for rail operations in a theater are the responsibility of the theater Army commander.

4 7. From consolidated data from all the TRB's, the highest echelon of TRS command in the theater develops the rail transportation plan for the entire theater.

4 8. The purpose of preinvasion rail planning is to provide a detailed picture of the capacity of a railroad in a particular theater of operations.

4 9. Reconnaissance of a rail line is made by the commander of the railway battalion that will operate the line.

Weight

SECOND GROUP

When determining the pulling power of locomotives, you know that:

4 10. The total weight of the locomotive affects drawbar pull.

4 11. Only that portion of the total locomotive weight that rests on its drivers affects tractive effort.

4 12. Under the Whyte classification system, locomotives are classified according to horsepower.

4 13. Drawbar pull equals the continuous tractive effort of a locomotive minus 20 pounds per ton of total locomotive weight.

4 14. The numerical sequence of wheel arrangements in the Whyte system is given from front to rear.

4 15. Leading and trailing truck wheels on U. S. Army diesel-electric locomotives are used to provide balance.

Matching

You are to match a phrase from column II to each term in column I. Items in column II may be used once, more than once, or not at all.

Column I

4 16. Tractive effort.

4 17. Drawbar pull.

4 18. Continuous tractive effort.

Column II

A. Pulling ability of a locomotive.

B. Horizontal force a locomotive can exert if the wheels do not slip.

C. Force tending to hold back the movement of a locomotive.

(Continued)

Weight

Column II

D. Power of a locomotive to move itself and its load from a stopped position.

E. Effort required to keep a train rolling.

Multiple Choice

(Each question in this group contains one and only one correct answer. Mark your choice by circling the correct answer.)

3 19. Assume that a steam locomotive weighing 130 STON can start a train weighing 675 STON. It can continue to haul approximately__________STON.

A. 675.

B. 525.

C. 475.

D. 350.

3 20. For a diesel-electric locomotive weighing 126 tons, using rule of thumb, you figure that the continuous tractive effort is_________pounds.

A. 30,350.

B. 31,500.

C. 57,250.

D. 63,000.

3 21. An 0-4-4-0 diesel-electric locomotive weighs 60 tons. The amount of its weight resting on its drivers is pounds.

Weight

A. 30,000.

B. 60,000.

C. 90,000.

D. 120,000.

3 22. A steam locomotive has 160 tons of weight resting on its drivers. Its starting tractive effort, by rule of thumb, is___________pounds.

A. 41,000.

B. 60,000.

C. 73,000.

D. 80,000.

3 23. An 0-6-6-0 diesel-electric locomotive weighs 135 tons. The drawbar pull of this locomotive is_____________pounds.

A. 22,210.

B. 23,150.

C. 31,050.

D. 34,090.

3 24. In determining the starting tractive effort of a given locomotive by the rule-of-thumb method, planners use an average of what part of the weight on drivers?

A. 1/4.

B. 1/2.

C. 2/3.

D. 3/4.

Weight

3 25. If a 150-ton steam locomotive is known to have a tractive effort of 42, 000 pounds, its drawbar pull is_____pounds.

A. 40,250.

B. 39,000.

C. 37,500.

D. 30,200.

3 26. A 120-ton diesel-electric locomotive has a starting tractive effort of 72, 000 pounds. Its drawbar pull is _____________pounds.

A. 72,800.

B. 60,000.

C. 45,900.

D. 33,600.

Analytical

(Using the following key, mark an "A", "B", or "C" next to each of the items below to indicate your reaction to them.)

A. The underscored statement is true, and the reason or result of it is true.

B. The underscored statement is true, but the reason or result is false.

C. The underscored statement is false.

3 27. <u>To get the tractive effort of a locomotive, you must first convert its weight from tons to pounds</u> because tractive effort is expressed in pounds.

<u>Weight</u>

3 28. <u>The continuous tractive effort of a diesel-electric locomotive is less than its starting tractive effort</u> because it has no leading or trailing wheels.

3 29. <u>Leading truck wheels of a 2-8-0 steam locomotive bear some of the locomotive's total weight</u>, but they do not affect tractive effort.

3 30. <u>The rear set of wheels on a diesel-electric locomotive are trailing wheels that bear some of the locomotive's weight</u>, but they do not affect tractive effort.

LESSON ASSIGNMENT SHEET

TRANS SUBCOURSE 603................Rail Operations Planning.

LESSON 2...........................Tonnage Capacity Determination (Continued)

CREDIT HOURS.......................4.

TEXT ASSIGNMENT....................Reference Text 603, pars. 2.6-2.23.

MATERIALS REQUIRED.................None.

LESSON OBJECTIVE...................To enable you to determine the capacity of a rail line in a theater of operations.

SUGGESTIONS

When making calculations, follow the sequence set forth in the examples in Reference Text 603. Use information in table I for computing drawbar pull. Raise any fraction encountered to the next higher whole number.

EXERCISES

<u>Weight</u> <u>Multiple Choice</u>

(Each question in the group contains one and only one correct answer. Make your choice by circling the alternative you believe to be the correct answer.)

5 1. On a single-track division where each train can haul a GTL of 1, 000 short tons, what is the net trainload in short tons ?

A. 500.

B. 2,000.

C. 2,500.

D. 3,000.

Weight

5 2. You have 12,000 STON of freight to haul, and only one locomotive is available. It can pull a GTL of 850 STON. How many trips will this locomotive have to make to move the freight?

A. 18.

B. 24.

C. 29.

D. 32.

5 3. The force acting parallel to the track and tending to retard the movement of a train is known as:

A. Grade resistance.

B. Force resistance.

C. Rolling resistance.

D. Track impedance.

5 4. The average value of rolling resistance per ton of train operating over a track classed as fair to poor is pounds.

A. 9.

B. 8.

C. 7.

D. 6.

5 5. What is the grade resistance for a rail line with a ruling grade of 3 percent?

A. 60.

B. 50.

Weight

C. 30.

D. 20.

5 6. You have been able to determine that, on a three-division railroad, the first division has an NDT of 5,455 STON and the second division NDT is 5, 225 STON. The GTL for the third division is 900 STON, and the train density is 11. What is the end delivery tonnage, in STON, for the railroad?

A. 4,760.

B. 4,950.

C. 5,225.

D. 5,455.

5 7. The loss in DBP of a locomotive in a region where the most adverse weather ranges between -36° and -40° is percent.

A. 45.

B. 40.

C. 35.

D. 30.

5 8. A standard-gage, single-track rail division is 93 miles long. The track is rated exceptionally good with a percent of ruling grade of 1.2. Passing tracks are located at mileposts 9, 20, 28, 39, 42, 51, 68, and 78. When you use the formula for determining TD, what is the train density for this division?

A. 14.

B. 12.

Weight

C. 11.

D. 9.

5 9. From the following information, what is the gross trailing load in short tons for a 65-ton, 0-4-4-0 diesel-electric locomotive?

Starting tractive effort.............39,000 pounds.
Weather..............................-1° to -10°.
Track................................Good to fair.
Ruling grade.........................2.3 percent.
Ruling curve.........................7.5.

A. 513.

B. 448.

C. 343.

D. 267.

5 10. Using the formula given in the text, determine the train density of the following single-track division:

Length of division...................138 miles.
Track................................Fair to poor.
Percent of ruling grade..............2.3.
Number of passing tracks.............16.

A. 11.

B. 12.

C. 13.

D. 14.

5 11. Each train on a single-track division can haul a GTL of 860 STON. The train density is 12. The net division tonnage is________short tons.

Weight

A. 5,160.

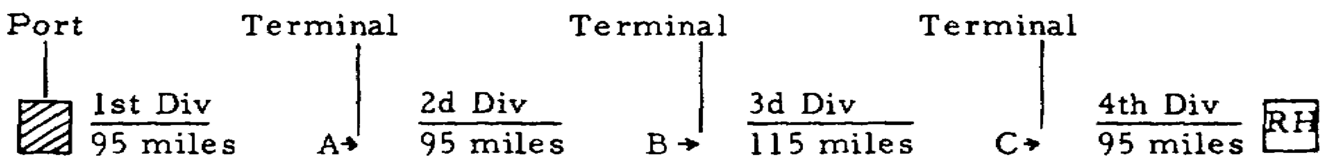
B. 4,480.

C. 3,884.

D. 3,204.

SITUATION

You are planning to operate a four-division, standard-gage, single-track railroad. The following data are available to you.



Track............1st Division........Exceptionally good.
2d Division.........Good to fair.
3d Division.........Exceptionally good.
4th Division........Fair to poor.

Ruling grade.....1st Division........1.5 percent.
3d Division.........1 percent.
3d Division.........2.9 percent.
4th Division........1 percent.

Ruling curve.....1st Division........2.5°.
2d Division.........7.5°.
3d Division.........10°.
4th Division........5°.

Temperature
(lowest expected). All Divisions....0° to +15° F.

Motive power.....1st, 2d, and 4th
Divisions...........0-4-4-0, 120-ton diesel-electric locomotives. Drawbar pull 33, 600 pounds.

Weight

3d Division.........Double-headed 0-6-6-0, 127-ton diesel-electric locomotives. Drawbar pull 35, 310 pounds each.

Train density . All Divisions.......10.

REQUIREMENT

Using the preceding information, find the solutions to the following nine problems.

5 12. The gross trailing load for the first division is STON.

A. 819.

B. 818.

C. 817.

D. 816.

5 13. The gross trailing load for the second division is STON.

A. 813.

B. 863.

C. 945.

D. 967.

5 14. The gross trailing load for the third division is STON.

A. 447.

B. 735.

C. 801.

D. 896.

Weight

5 15. The gross trailing load for the fourth division is STON.

A. 917.

B. 911.

C. 900.

D. 887.

5 16. The net trainload for the first division is_________STON.

A. 409.

B. 414.

C. 416.

D. 418.

5 17. The net trainload for the fourth division is________STON.

A. 469.

B. 459.

C. 454.

D. 450.

5 18. The net division tonnage for the second division is STON.

A. 4,000.

B. 4,050.

C. 4,580.

D. 4,730.

Weight

5 19. The net division tonnage for the third division is STON.

A. 4,680.

B. 4,660.

C. 4,480.

D. 4,460.

5 20. The end delivery tonnage for the railroad is________STON.

A. 4,420.

B. 4,300.

C. 4,160.

D. 4,090.

LESSON ASSIGNMENT SHEET

TRANS SUBCOURSE 603..........Rail Operations Planning.

LESSON 3......................Equipment and Personnel Requirements.

CREDIT HOURS.................3.

TEXT ASSIGNMENT..............Reference Text 603, paragraphs 3.1-4.7.

MATERIALS REQUIRED...........None.

LESSON OBJECTIVE.............To enable you to compute the amount and type of railway equipment and the number and kind of railway personnel required for operating a railroad in a theater of operations.

SUGGESTIONS

When making calculations, follow the sequence set forth in the examples in Reference Text 603. Raise any fraction encountered to the next higher whole number.

EXERCISES

<u>Weight</u> <u>Multiple-Choice</u>

(Each question in this group contains one and only one correct answer. Make your choice by circling the alternative you believe is the correct answer.)

5 1. The average workday for a road crew should not exceed hours.

A. 16.

B. 12.

C. 10.

D. 8.

Weight

5 2. If 1 day's dispatch is 349 cars at a port terminal, not counting the 10 percent for reserve, how many switch engines are needed for the rail yard at this terminal?

A. 7.

B. 9.

C. 11.

D. 13.

5 3. For planning purposes, an 8,000-gallon tank car can carry _____________gallons of liquid.

A. 8,000.

B. 6,000.

C. 4,000.

D. 2,000.

5 4. A railroad in a theater is being operated by 6 TRB's. What is the highest supervisory railway unit that would be assigned?

A. Transportation command.

B. Transportation railway brigade.

C. Transportation railway battalion.

D. Transportation railway group.

5 5. You are going to operate a five-division railroad in a theater of operations, consisting of a port terminal, four division terminals, and a railhead. Turnaround time for trains operated over the railroad is____________days.

Weight

A. 13.

B. 11.

C. 9.

D. 7.

5 6. The carrying capacity, or average payload, of a boxcar used by military planners is__________percent of its rated capacity.

A. 25.

B. 50.

C. 75.

D. 100.

5 7. How many road crews are needed for a proposed single-track division 96 miles long? The track can handle 12 trains per day each way, and the average train speed is 10 mph.

A. 36.

B. 34.

C. 33.

D. 30.

5 8. The end delivery tonnage is 2, 795 short tons for a two-division railroad with a port and a railhead. Sixty percent of the EDT is to be hauled in 40-ton boxcars and 40 percent in 40-ton flatcars (rated capacities). How many of each type of rolling stock are in 1 day's dispatch?

A. 78 boxcars and 51 flatcars.

B. 84 boxcars and 56 flatcars.

C. 89 boxcars and 62 flatcars.

D. 94 boxcars and 67 flatcars.

<u>Weight</u>

5 9. With the use of the formula for determining road engine requirements, how many road engines are needed on-a rail division that has a train density of 15, an average train speed of 10 mph, and a length of 120 miles? Steam locomotives are used.

A. 30.

B. 28.

C. 26.

D. 24.

5 10. If 1 day's dispatch is 560 cars, how many switch engines are needed at the railhead, excluding reserves?

A. 15.

B. 17.

C. 19.

D. 21.

5 11. One day's dispatch for a two-division railroad consists of 56 boxcars, 45 gondolas, and 12 flatcars. What are the total rolling stock requirements for the railroad?

A. 872.

B. 883.

C. 895.

D. 907.

5 12. A railroad has 17 switch engines, 5 of which are kept in reserve. How many switch crews are needed?

Weight

A. 50.

B. 40.

C. 30.

D. 20.

SITUATION

You are planning to operate a railway division with a train density of 15, length of 99 miles, a track rated as poor, and a percent of ruling grade of 2.83. It has already been determined that you will need 8 switch engines for the operation.

REQUIREMENT

Answer the following two multiple-choice questions based on the preceding information.

5 13. How many road crews will you need to operate the division?

A. 67.

B. 63.

C. 58.

D. 51.

5 14. The number of switch crews needed to operate the division is?

A. 19.

B. 20.

C. 21.

D. 22.

Weight

SITUATION

You are planning a three-division rail operation. The end delivery tonnage for the railroad is 3,800 STON. You intend to ship 60 percent of the EDT in 40-ton boxcars, 30 percent in 40-ton gondolas, and 10 percent in 20-ton foreign flatcars (rated capacity.)

REQUIREMENT

Answer the following four multiple-choice questions based on this information.

5 15. How many boxcars will you need to operate the railroad?

A. 853.

B. 1,035.

C. 1,120.

D. 1,129.

5 16. How many gondolas will you need to operate the railroad?

A. 750.

B. 655.

C. 565.

D. 511.

5 17. To operate the railroad, you will need__________flatcars.

A. 340.

B. 360.

C. 377.

D. 401.

Weight

5 18. How many switch engines will you require at each division terminal?

A. 9.

B. 7.

C. 5.

D. 3.

SITUATION

You are planning to operate a five-division railroad in a theater of operations. It has already been determined that the following numbers of road and switch crews will be needed as specified.

1st division.........................45 crews.
2d division..........................39 crews.
3d division..........................38 crews.
4th division.........................46 crews.
5th division.........................47 crews.

REQUIREMENT

Answer the following two multiple-choice questions based on this situation.

5 19. How many railway battalions should be assigned for the rail operation?

A. 3.

B. 5.

C. 7.

D. 9.

Weight

5 20. Having decided on the number of battalions you need, what supervisory unit would you assign?

A. Transportation command.

B. Transportation railway brigade.

C. Transportation railway group.

D. Transportation railway battalion.

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True or False

(Mark next to the item a "T" for true and an "F" for false.)

Weight

5 1. Both oil and coal requirements for steam locomotives are computed by the same method except for the percentage allowed for contingencies.

5 2. Train miles are computed separately by division for each type of road locomotive used in the operation.

5 3. Switch-engine fuel requirements are based on the amount used per train mile.

5 4. A reserve factor of 10 percent for coal and 5 percent for oil is added to the monthly requirements to allow for contingencies.

SITUATION

You are going to operate a three-division railroad in a theater of operations. You have the following information about each of the divisions:

	1st Div	2d Div	3d Div	Railhead
Length (miles)	145	100	110	
Train density	15	13	11	
Road engines	13	12	13	
Switch engines	5	3	3	5

Motive power: 0-4-4-0, 60-ton diesel-electric locomotives for all divisions.

REQUIREMENT

Using the preceding information, answer the following matching questions.

Compute the monthly spare-parts requirements for the railroad and match the appropriate quantities from column II to the spare parts listed in column I. Items in column II may be used once, more than once, or not at all.

Weight		Column I		Column II
5	5.	Spare parts, 1st Div.	A.	33 STON.
5	6.	Spare parts, 2d Div.	B.	39 STON.
5	7.	Spare parts, 3d Div.	C.	45 STON.
5	8.	Spare parts, entire railroad.	D.	117 STON.
			E.	119 STON.

Compute the monthly supply requirements for the railroad and match the appropriate quantities from column II to the supplies listed in column I. Items in column II may be used once, more than once, or not at all.

		Column I		Column II
5	9.	Lubricants, 1st Div.	A.	26,000 lb.
5	10.	Lubricants, 2d Div.	B.	78,000 lb.
5	11.	Lubricants, 3d Div.	C.	80,640 gal.
5	12.	Lubricants, entire railroad.	D.	22,000 lb.
			E.	30,000 lb.
5	13.	Fuel for the switch engines		

Multiple -Choice

(Each of the following questions contains one and only one correct answer. Mark your choice by circling the alternative you believe to be the correct answer.)

5 14. If you were computing the fuel requirements for 0-6-6-0, 120-ton diesel-electric locomotives used in switching service, you would multiply the number of switch engines by 20 and the result by:

Weight

A. 6.0.

B. 6.4.

C. 11.5.

D. 450.

5 15. You are computing the amount of fuel required to operate your division's oil-burning steam locomotives in road service each month. You have computed the daily requirement and multiplied it by 30 to get 2,740 tons. You get the total required for the month by adding_____to this figure.

A. 125.

B. 137.

C. 274.

D. 315.

5 16. You want to compute the amount of coal required each month for the 2-8-0, 82-ton steam locomotives your division will use in road service. You have determined the train miles per day and multiplied it by 90 pounds, the fuel consumption factor. Your next step is to:

A. Add 5 percent to the product.

B. Multiply the product by 30.

C. Multiply the product by 10 percent.

D. Divide the product by 2,000.

5 17. A division of railroad using 127-ton diesel-electric locomotives operates 900 train miles per day. How many gallons of fuel will its road engines require daily?

Weight

A. 5,400.

B. 3,600.

C. 2,700.

D. 1,800.

5 18. A division of railroad operates 10 trains daily from its origin terminal to the railhead. The estimated amount of lubricants required each month is__________pounds.

A. 20,000.

B. 15,000.

C. 10,000.

D. 5,000.

Analytical

(Using the following key, indicate your reaction to each of the statements. Write "A", "B", or "C" next to each of the statements.)

A. The underscored statement is true, and the reason for it or result of it is true.

B. The underscored statement is true, but the reason or result is false.

C. The underscored statement is false.

5 19. Train density is a very important factor in determining lubricant and spare parts requirements for a railroad because they are based on the number of trains operated over the railroad each day.

5 20. A division using two 82-ton steam locomotives, one coal and one oil-burning, would plan to use more oil than coal because the estimated consumption of oil is 5 percent more than that of coal.

REFERENCE TEXT
603

RAIL OPERATIONS PLANNING

The information contained herein is provided for instructional purposes only. It reflects the current thought of this school and conforms to printed Department of the Army doctrine as closely as possible. Development and progress render such doctrine continuously subject to change.

U. S. ARMY TRANSPORTATION SCHOOL
Fort Eustis, Virginia

CONTENTS

INTRODUCTION

Railroads are an effective and efficient form of transportation in a theater of operations. They can haul heavy loads long distances with a minimum of motive power, they are less hampered by variations of adverse weather than any other mode, and they can move almost any commodity. In addition to these advantages over other modes of transportation, the useful carrying capacity of railway trains is not limited by the fuel they must carry.

These advantages of rail transport can be fully exploited only when operations are carefully planned and skillfully carried out. Trains must be operated according to a well-made movements plan that is a part of the overall plan to support military activities in a theater of operations. The information in this text explains how the rail operations part is made. One day you might be given the responsibility for its preparation; what will you need to know?

First, you want to know who is responsible for planning, where it takes place, and where the intelligence information used to make the plan comes from. The information in chapter 1 answers these questions.

Second, you want to know how to answer the big question, How many short tons of freight can be delivered at the forward end of a particular railroad each day? To answer this, you must determine the capacity of that railroad. You may not be able to answer the question precisely, but the explanations in chapter 2 should enable you to make a close estimate.

The next discussions, in chapter 3, explain how to plan for the equipment required for the rail operation. The three basic types of equipment are road engines, switch engines, and rolling stock. Your plan must show the amount of each type you will need.

The fourth thing you must be able to determine is the number of people and the kind of railway organization the operation requires.

Chapter 4 explains how to compute these figures and discusses how rail units are organized and the basis on which they are assigned.

Finally, you need to know how much of what kind of railway supplies are required to support the rail operation. The final chapter in the text explains how to compute these requirements.

For your convenience in making computations, all tables and formulas in the text are reproduced in annex A.

Chapter 1

PLANNING AND INTELLIGENCE

1.1. GENERAL

The transportation railway service (TRS) is responsible for operating and maintaining railroads in a theater of operations. It uses rail lines, rail equipment, and rail facilities that exist already in the theater; the only construction materials and rail equipment brought into the theater are those needed to support military activities.

Because of the large potential carrying capacity of trains, the rail system in a theater should begin operations as soon as possible after the theater is established. This isn't as simple as it sounds. Railroading is a complex business that requires careful planning--particularly military railroading in war-torn areas. Who does the planning? What information is needed? Where does the information come from? These questions are answered in this chapter. The discussion begins with the planning that takes place long before military forces enter a theater of operations.

1.2. PREINVASION PLANNING

The transportation railway service has a major part in preinvasion planning for logistical support in a theater where railroads are a major means of transportation. Taking place within the zone of interior (ZI), the rail planning begins long before the date set for invasion. The plan made is necessarily a broad one, and it is based upon any and all intelligence data on hand. However, as more information becomes available or when any changes in the rail system in the theater are made, the plan is modified. The purpose of preinvasion rail planning is to provide general estimates of the potential movements capability of a particular railway system in a given theater.

Once the invasion begins or perhaps even before it begins, the entire picture of the railway system starts to change. The preliminary bombardment, both aerial and surface, causes considerable damage to railroads in the area. Also, as enemy forces retreat they usually blow up or tear up as much of the rail lines, facilities, and equipment as they can to deny the advancing forces immediate use of the railroads. As soon as possible after our military forces are engaged with the enemy, the rail planning moves from the ZI to the theater.

1.3. PLANNING IN A THEATER OF OPERATIONS

The staff and planning functions for rail operations in a theater are the responsibility of the commander of the highest echelon of TRS command in the theater. The railway plan he develops is integrated into the overall movements plan for the theater.

As stated in the preceding paragraph, the broad plan developed in the ZI begins to be modified in keeping with the changes taking place as the actual invasion begins and the theater develops. The plan must be tailored to the mission, environment, and enemy capabilities; it must be suited to the type of warfare, conventional or nuclear. How does the planner know what changes have occurred in the railway system? Reconnaissance is the answer.

The earliest possible reconnaissance of captured or liberated rail lines in a theater is the responsibility of the commander of the highest echelon of TRS command. The actual reconnaissance is made by selected personnel of the transportation railway battalion (TRB) or battalions, augmented by intelligence personnel from higher rail units whenever necessary. This is how it happens.

The railway battalion commander who has been assigned a division of rail line to operate makes a reconnaissance of his division. He then makes an estimate of the time it will take to get the line operational and the capacity of the line in terms of the net tonnage that can be moved over it. His estimates are based on the gage, length, grade, and curvature of the line; the type of equipment available; and the kind and number of facilities available for use. All the information he is able to obtain and the plans and estimates he makes are forwarded to the transportation railway group, which let us suppose in this instance, is the highest echelon of TRS command. At group headquarters, all the

information and estimates from all the battalions are consolidated to form the rail transportation plan and forwarded to the transportation command, theater army support command (TASCOM). Here the assistant chief of staff, movements, integrates it into the overall movements plan for the theater.

At this point the first question asked in paragraph 1.1 has been answered. We know who does the planning and where. Next, we need to know what information is required for planning.

1.4. INTELLIGENCE DATA NECESSARY FOR PLANNING

Railway planning consists primarily of making estimates of the capacity of a rail line, the personnel necessary to operate and maintain it, and the equipment and supplies required for it. Certain intelligence data to base these estimates on are essential. When all the needed data are available, planning the operation is somewhat simplified. However, if the required information is not available and cannot be readily obtained, the planner must make assumptions based on what information he does have and on experience gained in past rail operations. Some of the more important things a planner needs to know to plan his operation are discussed in the following subparagraphs.

a. Details shown on maps and photographs, both ground and air, such as the rail routes, the number and location of railway facilities, and the number and kind of structures are invaluable to the planner.

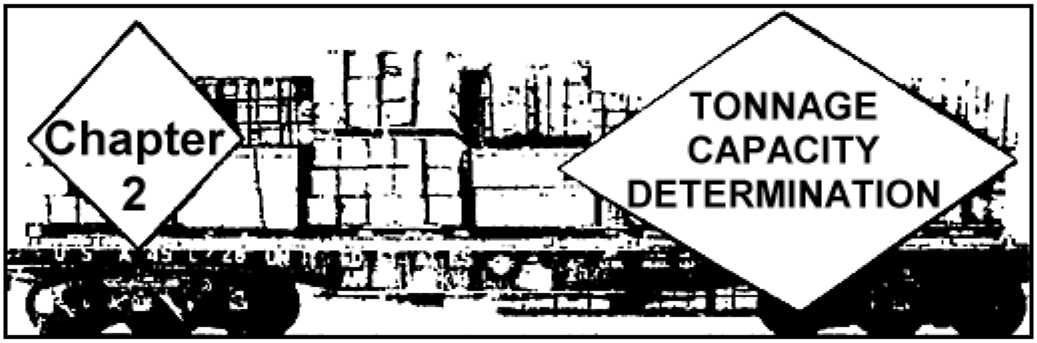
b. A general description of the rail system, its facilities, and its equipment aids the planner in determining the potential capacity of the system. The description should give information about the ownership of the railroad, general operating procedures, railway organization, and the importance of the system in the economic structure of the country in which it is located.

c. Detailed basic characteristics of routes, facilities, equipment, structures, and operations increase the accuracy of a planner's rail capacity estimates. Intelligence data should include details on such items as right-of-way, roadbed, and track; types and amount of equipment; supply and maintenance factors such as spare parts, enginehouse facilities, and locomotive fueling and watering stations; and availability of personnel.

1.5. SUMMARY

The initial planning for a rail operation in a theater begins in the zone of interior, and the plan, based on whatever intelligence data are available, is necessarily broad. Once the invasion has begun and rail units are phased into the theater, rail planning moves from the ZI to the theater, where it is integrated into the overall theater transportation plan. As changes in the rail system develop and more information becomes available, the plan is modified and becomes more specific and detailed. The greatest modification of the plan results from an on-the-spot reconnaissance made by the TRB commander, selected personnel from his unit, and intelligence personnel from higher rail units when necessary. The new information and the modified plan are passed up the TRS chain of command where, at each level, the plan and the data are consolidated with those from other railway units.

Because of the large tonnage movement capability of a railroad, rail operations should begin as soon as possible after the theater is established. Without fairly accurate planning, however, there might be serious delay in beginning the operation. A planner may not always have all the information he would like to have to plan his operation, but he can make assumptions based on what information he does have and on records of experience gained in rail operations in previous theaters.



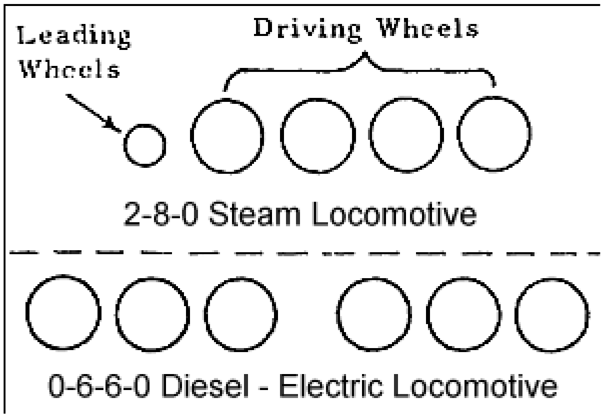
2.1. GENERAL

The most important part of making a plan for rail operations is determining how many tons of supplies and equipment can be moved over the rail line and delivered at its forward end each day. The line may be a short stretch of single track, or it may be one or more rail divisions each ranging from 90 to 150 miles (145-241 kilometers) in length. The capacity of each division or branch line must be determined separately. The three principal things you must know before you can make an accurate determination of the capacity of any rail line are the pulling or hauling power of the locomotives you will use, the resistance offered to the pull of the locomotives, and the number of trains that can be operated over the line each day. Once this information is known, you can determine the net tonnage for a division of railroad; when you know the net tonnage for every division of the railroad, you can estimate the number of tons that can be delivered at the forward end of the line each day. This chapter explains exactly how to determine the tonnage capacity of a rail line.

2.2. TYPES AND CLASSIFICATION OF LOCOMOTIVES

Transportation railway service personnel use most of the rail equipment they find in a theater. Most foreign countries use steam locomotives, diesel-electric locomotives, or both. While the TRS does not generally plan to use steam locomotives, they may be the only type in use in the theater; therefore, this text discusses both.

Locomotives are classified in several ways, but the Army uses the Whyte classification system to classify both steam and diesel-electric locomotives. This system identifies the wheel arrangements of locomotives. Locomotive wheels are grouped as leading, driving, and trailing wheels. Numerals separated by hyphens represent the number of wheels in each group, starting at the front end of the locomotive. For a steam locomotive, the first figure denotes the number of wheels in the lead truck, the second represents the number of drive wheels, and the last figure the number of wheels in the trailing truck. Tender wheels are not included. An illustration of the Whyte system showing the wheel arrangements of two locomotives is shown in the inserted sketch. Since the wheel arrangement represents a side view of the locomotive only one wheel of each pair is shown. The 2-8-0 steam locomotive shown in the illustration has 2 leading wheels, 8 coupled driving wheels, and no trailing wheels. The wheels of the leading trucks are nondriving. Army diesel-electric locomotives have no leading or trailing wheels; this is denoted by a zero. The 0-6-6-0 diesel-electric locomotive shown in the illustration has six driving wheels on the front truck assembly and six on the rear truck assembly with no leading or trailing wheels.



The Whyte classification system is generally accepted in Great Britain and the British Commonwealth and in North and South America. Another system, commonly used in Europe and other parts of the world, uses letters and figures to identify a diesel or electric locomotive by its axles. Letters are used for driving axles and numbers for nondriving axles. In this system, "A" stands for one driving axle, "B" for two, "C" for three, and "D" for four. A small "o" placed after the initial letter shows that each axle is individually powered. Thus, a single unit locomotive with two individually powered two-axle trucks would be classified as a Bo-Bo. One with three axle trucks in which the center axle is an idler would be designated as an A1A-A1A.

The wheel arrangements as designated by the Whyte system are particularly important because they indicate the number of driving wheels a locomotive has. The pulling capacity of a locomotive is directly related to the number of driving wheels (drivers) and the amount of weight that rests on them.

2.3. WEIGHT ON DRIVERS

The amount of a locomotive's weight that rests on its drivers is expressed in pounds or short tons (STON) of 2,000 pounds each. All tons mentioned in this text are short tons; therefore the terms "ton" and "short ton" are used interchangeably. The distribution of weight on drivers differs between steam and diesel-electric locomotives; this difference is explained in the following subparagraphs.

a. Steam locomotives. An illustration of the distribution of weight of a 2-8-0 steam locomotive and tender is shown in figure 1.1. Notice that the locomotive and tender weigh 296,350 pounds, but only that portion of the total weight that rests on the driving wheels, 141,500 pounds, affects the work capacity or pulling power of the locomotive.

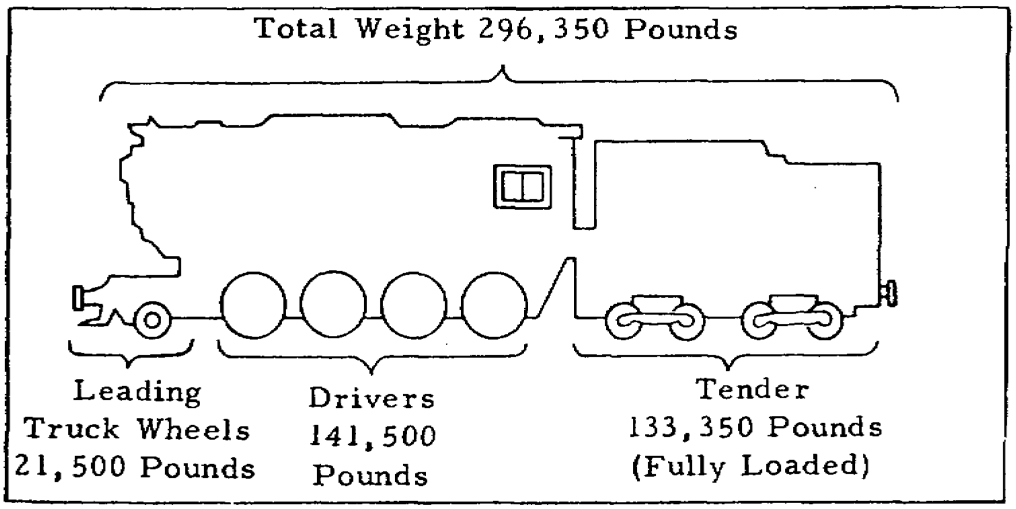


Figure 1.1. Weight Distribution of a 2-8-0 Steam Locomotive.

b. Diesel-Electric locomotives. The weight distribution of a diesel-electric locomotive is different from that of a steam locomotive because the diesel has no tender, leading trucks, or trailing trucks. All wheels on Army diesel-electric locomotives are driving wheels. The entire weight of this type of locomotive is evenly distributed on the driving wheels, as illustrated in figure 1.2, and they all affect its pulling power.

2.4. TRACTIVE EFFORT

Tractive effort (TE), expressed in pounds, is the potential power of a locomotive. It is the horizontal force or power that a locomotive can exert on straight, level track if the wheels do not

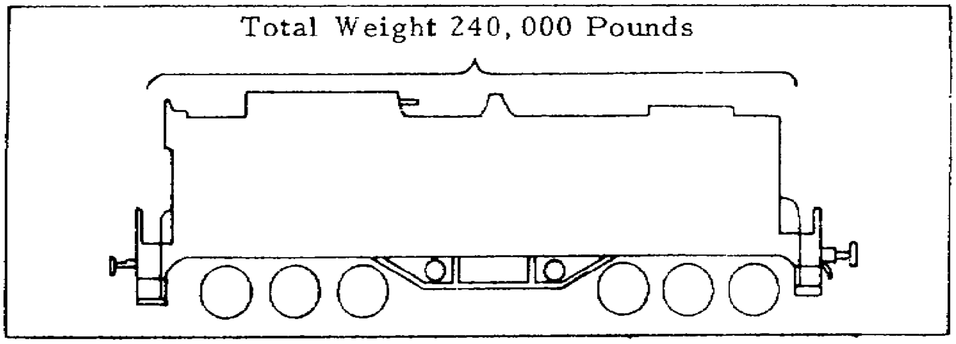


Figure 1.2. Weight Distribution of an 0-6-6-0 Diesel-Electric Locomotive.

slip. A locomotive's tractive effort is included in the data supplied by the manufacturer. The starting tractive effort for some of the locomotives used by the Army is given in table I along with other characteristics. The diesel-electric locomotives listed in the table are designed for both road and switcher service and are therefore called road switchers. Whenever data on a particular locomotive are not available, several formulas can be used to determine its tractive effort depending upon its type. However, for military planning purposes, a rule-of-thumb method for this determination is adequate. Explanations in this text are confined to the rule-of-thumb method; it is explained in subparagraph b following an explanation in subparagraph a of the important difference between starting and continuous tractive effort.

a. Starting and continuous tractive effort. The power of a locomotive to move itself and the load it is hauling from a stopped position is called starting tractive effort. Continuous tractive effort is the effort required to keep a train rolling once it has been started. The starting and continuous tractive efforts for a steam locomotive are the same, because it can continue to move anything it can start. On the other hand, a diesel-electric locomotive cannot continue to exert maximum power for a prolonged period without damaging its traction motors; therefore, its continuous tractive effort is rated at 50 percent of its starting tractive effort.

b. Rule-of-thumb method of determining tractive effort. Starting tractive effort is directly related to the adhesion between the driving wheels and the rails. If the power applied to the driving wheels exceeds the amount of adhesion, the drivers slip. When the rails are dry, the amount of adhesion is about 30 percent of the weight on drivers; when the rails are wet, 20 percent. Therefore, the rule of thumb for determining tractive effort is to average the two; that is, 25 percent of the weight on drivers of a locomotive is

Table I. Characteristics of United States Army Locomotives

Type of Locomotive	Weight on Drivers (STON)	Starting TE (lb)	Total Weight (STON)	Maximum Curvature Transversible Degrees
Standard to broad gage (56 1/2-in, 60-in, 63-in, and 66-in gage).				
0-6-6-0 diesel-electric, 131-ton, 1,000 horsepower, road switcher.	131	75,700	131	24+
0-6-6-0 diesel-electric, 127-ton, 1,000 horsepower, road switcher.	127	75,700	127	24+
0-4-4-0 diesel-electric, 120-ton, 1,200 horsepower, road switcher.	120	72,000	120	29+
0-4-4-0 diesel-electric, 65-ton, 400 horsepower, road switcher.	65	39,000	65	75
2-8-0 steam, 80-ton, road	70	34,100	146	25

NOTE: The starting TE given in this table may also be used as the continuous tractive effort for steam power. For diesel-electric power, the continuous TE is one-half of the starting TE.

its starting tractive effort. For example, if a diesel-electric locomotive has 200,000 pounds of weight on its drivers, its starting tractive effort is 50,000 pounds.

$$200,000 \times .25 = 50,000$$

The continuous tractive effort for this locomotive is only 50 percent of its starting tractive effort, or 25,000 pounds.

2.5. DRAWBAR PULL

The drawbar pull (DBP) of a locomotive is its actual pulling ability; it is the tractive effort less the effort necessary to move the locomotive itself. In other words, DBP is the effort the locomotive has left after it moves itself. Tests have shown that it takes from 16 to 20 pounds of pull per ton to start the average locomotive or freight car on straight, level track in fair weather with moderate temperatures. If the locomotives or freight car is equipped with roller bearings, starting effort required is somewhat less. However, for military planning purposes, 20 pounds per ton of total locomotive weight is subtracted from the continuous tractive effort of the locomotive to establish pulling ability for starting and pulling a train; this is the force that can be applied at the drawbar of the locomotive.

It is emphasized that maximum drawbar pull can be exerted only at low speeds--up to 10 miles per hour (mph)--after which it drops off sharply. Drawbar pull at speeds above 10 miles per hour can be obtained by applying a speed factor to the maximum DBP; however, speed factors are not included in this text because trains in a theater rarely travel at average speeds above 10 miles per hour.

For a diesel-electric locomotive weighing 90 tons and having a continuous tractive effort of 22,500 pounds, drawbar pull is computed as follows:

$$
\begin{array}{rl}
90 \text{ tons} & = \text{total locomotive weight.} \\
\underline{\times\ 2{,}000 \text{ lb}} & = \text{number of pounds per ton.} \\
180{,}000 \text{ lb} & = \text{total locomotive weight.}
\end{array}
$$

$$
\begin{array}{rl}
180{,}000 \text{ lb} & \\
\underline{\times\ \ .25} & \\
900000 & \\
\underline{360000\ \ } & \\
45{,}000.00 \text{ lb} & = \text{starting tractive effort.}
\end{array}
$$

$$
\begin{array}{rl}
45{,}000 \text{ lb} & \\
\underline{\times\ \ .50} & \\
22{,}500.00 \text{ lb} & = \text{continuous tractive effort.}
\end{array}
$$

Subtract 20 pounds per ton of total locomotive weight from the continuous tractive effort to get drawbar pull.

	90 tons	= total locomotive weight.
x	20 lb	
	1,800 lb	= number of pounds to be subtracted from continuous tractive effort.

22,500 lb	= continuous tractive effort
-1,800 lb	
20,700 lb	= drawbar pull.

In figuring the drawbar pull for a steam locomotive, remember that the starting and continuous tractive efforts are the same.

Once you have determined how much a locomotive is capable of pulling, the next step is to find out how much resistance is offered in opposition to that pull. Three forms of resistance that oppose the pull of a train, caused by the train and the track it runs on, are rolling, grade, and curve. A fourth, referred to as the weather factor, is a measure of the decreased efficiency of a locomotive in cold weather. Each of these forms of resistance is discussed separately in the next four main paragraphs.

2.6. ROLLING RESISTANCE

The forces acting upon a train in a direction parallel to the track and tending to hold back its movement are called rolling resistance (RR). This resistance takes many forms: the friction between the heads of the rails and the flanges and treads of the wheels, undulation of the track beneath a moving train, internal friction of the rolling stock, and friction and pressure of the air through which the train is moving. An absolute figure to represent rolling resistance is unknown, but experience with train movements in theaters of operations has produced some safe average values, as shown in table II. This table shows what value to use for rolling resistance expressed in pounds per ton of train. The value chosen depends on the overall quality of the track. Items such as ballast, ties, rails, and tie plates must be evaluated in determining the track's quality. No set policies or rules are available that indicate which track features cause which condition of track; the choice depends solely on experience. For planning purposes, however, this may be obtained from the detailed railway construction or rehabilitation plan of the engineers.

Table II. Average Values of Rolling Resistance (RR)

Track	Pounds per ton of train
Exceptionally good	5
Good to fair	6
Fair to poor	7
Poor	8
Very poor	9

As shown in table II, the poorer the track the higher the resistance factor that must be used in determining how much weight you can attach behind a locomotive and expect it to pull. For example, the value of RR is 7 pounds per ton of train for fair to poor track. This means that for each ton of a train, 7 pounds of force must be used to overcome rolling resistance.

2.7. GRADE RESISTANCE

The resistance to the progress of a train offered by a grade is called grade resistance (GR); caused by gravity, it tends to pull the train downhill. In the formula that follows, grade resistance is shown as being equal to 20 pounds per ton of train for each percent of grade. This means that 20 pounds of force must be exerted to move 1 short ton of train up each 1 percent of grade. In railroading, the percent of grade is an expression of the number of feet of vertical rise per 100 feet of horizontal distance. For example, if a 100-foot section of track rises 2 feet, the percent of grade for that section is 2. In planning for the operation of trains, the military planner is primarily interested in the maximum or ruling grade--the grade that limits the tonnage a locomotive can pull. Therefore, the percent of grade given in the formula is an expression of the amount of rise per 100 feet of the ruling grade for a given rail line. Grade resistance, then, is found by multiplying 20 pounds per ton of train by the percent of the ruling grade.

$$GR = T \frac{r}{b}$$

where

GR - grade resistance.

T = one ton (2,000 pounds).

r = percent of ruling grade.

b = one station (100 feet)

thus, GR in pounds per ton may be expressed as:

$$GR = \frac{2,000 \times \text{percent of ruling grade}}{100}$$

or.

$$GR = 20 \times \text{percent of ruling grade.}$$

Assume that the percent of the ruling grade for a division of railroad is 2.3. You can find the grade resistance as follows:

GR = 20 x 2.3 = 46.0, or 46 pounds per ton of train.

2.8. CURVE RESISTANCE

A curve is necessary each time a rail line changes direction, and it offers resistance to the progress of a train. No exact means of determining curve resistance (CR) has been published; however, military planners use 0.8 pounds per ton of train per degree of curvature. This means that 0.8 pounds of force or power must be exerted to move one ton of train around each degree of curvature in the ruling or sharpest curve on the line. For example, if the ruling curve for a rail division is 10°, you find the curve resistance for that line by multiplying 0.8 by 10. The CR is 8 pounds per ton of train.

2.9. WEATHER FACTOR

Weather factor (W) is a percentile expression of the adverse effects of cold and wet weather on the hauling power of a locomotive. Experience and tests have proved that when the outside temperature drops below 32° F., the hauling power of a locomotive decreases. This decrease results mainly from the changed tolerances between moving parts of the locomotive caused by contraction of metal and the increased loss of heat energy from the engine at low temperatures. Table III gives the loss in hauling power for various degrees of temperature and also the corresponding weather factor, both in percent. Look under the temperature column of the table and find

-1° to -10° F.; note that 15 percent of the hauling power is lost and the corresponding weather factor is 85 percent, the percentage of hauling power the locomotive retains when the temperature is in this range.

Table III. Effect of Weather Upon Hauling Power of Locomotives

Most adverse temperature in °F.	Loss in hauling power (percent)	Weather factor (percent)
Above +32	0	100
+16 to +32	5	95
0 to +15	10	90
-1 to -10	15	85
-11 to -20	20	80
-21 to -25	25	75
-26 to -30	30	70
-31 to -35	35	65
-36 to -40	40	60
-41 to -45	45	55
-46 to -50	50	50

Wet weather is usually regarded as local and temporary, and loss of hauling power caused by it is absorbed by average figures. Therefore, no reduction in hauling power is normally made for wet weather. In some areas of the world, however, where there are extended wet seasons such as monsoons and heavy fogs, a loss in tractive effort due to slippery rails may be serious if adequate sanding facilities are lacking. The amount of reduction that the planner should use in these areas is a matter of judgment; but, in general, he should not use a figure for it less than 20 percent of the weight on drivers.

2.10. GROSS TRAILING LOAD

Once you have found the potential power in a locomotive and the reasons that all of this power cannot be used to haul freight, the next step in planning is to determine how much weight in railway cars and freight can be attached behind and moved by a particular locomotive. This weight is known as the gross trailing load (GTL). Expressed in short tons, GTL is the maximum weight or load that a locomotive can safely pull behind it over a given line in known weather. It is determined by using the following formula which combines the factors discussed in paragraphs 2.5 through 2.9.

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

where

CTL = gross trailing load

DBP = drawbar pull

W = weather factor

RR = rolling resistance

GR = grade resistance

CR = curve resistance

NOTE: Throughout this text, raise all computations resulting in fractions to the next higher whole number.

If trains are double-headed or if pushers are used, the GTL is equal to the sum of the GTL's for all locomotives used multiplied by 90 percent for steam locomotives and 100 percent for diesel-electric locomotives. Double heading means coupling two or more locomotives to the head end of a train; pushers are one or more locomotives coupled at the rear end of the train. An example demonstrating how to find GTL is presented in the next main paragraph; it is essential in determining the net trainload, net division tonnage, and end delivery tonnage, discussed later in the text.

2.11. EXAMPLE OF GTL DETERMINATION

You are going to operate a railway division of 100 miles in a theater of operations during the winter. You have the following information about the railroad, and you wish to use it to determine GTL.

Locomotives - 0-6-6-0 diesel-electrics, each with a total weight of 240, 000 pounds (120 tons), a starting tractive effort of 72,000 pounds, and a continuous tractive effort of 36,000 pounds

Weather - Cold, with lowest temperatures ranging between -11° and -20° F.

Trackage - Single-track, standard gage, fair to poor

Grade - Percent of ruling grade = 1.5

Curvature - Sharpest or ruling curve 100

To use the formula for CTL given in the preceding paragraph, you must first find values for DBP, W, RR, GR, and CR.

a. Drawbar pull. Your locomotives have a continuous tractive effort of 36,000 pounds from which 20 pounds per ton of total locomotive weight must be subtracted to get DBP. Thus:

$$\begin{array}{rl} 120 & = \text{total locomotive weight} \\ \times\ \underline{20} & \text{lb} \\ 2{,}400 & \text{lb} = \text{amount to be subtracted from continuous tractive effort.} \end{array}$$

$$\begin{array}{rl} 36{,}000 & \text{lb} = \text{continuous tractive effort} \\ \underline{-2{,}400} & \text{lb} \\ 33{,}600 & \text{lb} = \text{drawbar pull} \end{array}$$

b. Weather factor. In table III, you find that between -11° and -20° F. a locomotive loses 20 percent of its hauling power; therefore, the weather factor is 80 percent. This means that the locomotive is able to exert only 80 percent of its normal hauling power.

c. Rolling resistance. In table II, you find that the rolling resistance is 7 pounds per ton of train on a track rated fair to poor. The value you must use for RR then is 7.

d. Grade resistance. Paragraph 2.7 explains that grade resistance is equal to 20 pounds per ton of train multiplied by the percent of ruling grade, which is 1.5 for your railway division. When you multiply 1.5 by 20 you get 30--the value for GR.

e. Curve resistance. Curve resistance is found, as explained in paragraph 2.8, by multiplying 0.8 pounds per ton of train per degree of curve. In this example, 0.8 multiplied by 100 gives you a CR value of 8.

f. Using the formula. Substitute the values you have found for the factors in subparagraphs a through e in the formula for GTL as follows:

$$GTL = \frac{DBP \times W}{RR + GR + CR} \quad \text{or}$$

$$GTL = \frac{33,600 \times .80}{7 + 30 + 8} \quad \text{or}$$

$$GTL = \frac{26,880}{45} \quad \text{or}$$

$$GTL = 597 +, \text{ or } 598 \text{ short tons}$$

g. Double-heading trains or using pushers. If you use two of the locomotives for each train, as in double-heading, the GTL is 1,196 short tons which you find by adding the GTL for each locomotive. If you were using steam locomotives, you would use only 90 percent of the combined GTL because this is the efficiency that steam locomotives retain when double-headed.

2.12. NET TRAINLOAD

The payload or actual weight of freight a train carries is the net trainload (NTL). It is the difference between the total weight of the cars under load and the same cars empty, or the gross trailing load minus the weight of the empty cars. Military planners do not total the weight of all cars in a train and subtract, but rather assume that 50 percent of the gross trailing load is payload. Using the example presented in the preceding paragraph, the GTL for a single 0-6-6-0 diesel-electric locomotive is 598 short tons. The net trainload for that locomotive on that division is 50 percent of 598 short tons or 299.

$$\begin{array}{rl} 598 \text{ STON} & = \text{GTL of the locomotive} \\ \underline{\times .50} & = \text{percent of GTL that is NTL} \\ 299 & = \text{NTL} \end{array}$$

If each train carries a net trainload of 299 short tons, you find the total number of payload tons or net division tonnage that can be moved over a rail division each day by multiplying the NTL by the number of trains that run over the division each day. The following paragraph explains how to determine just how many trains you can safely operate.

2.13. TRAIN DENSITY

The number of trains that can be safely operated over a rail division in each direction during a 24-hour period is the train density

(TD) for that division. Work trains are not included in computing train density; however, their presence and the amount of time they block the main line can reduce the TD of a rail division. Train density varies on different divisions, depending on the length and number of tracks of the main line; number and location of passing tracks; capacity of yards and terminals; signal and communications systems; method and procedures of train movement; and availability of traincrews, motive power, and rolling stock.

On a single-track line, passing tracks should be from 6 to 8 miles apart so that trains can meet and pass; however, a passing track within 5 miles of another is not expected to affect train density.

A rule-of-thumb method and a formula for determining train density for a rail division are presented in the following subparagraphs. When you do not have enough information on a rail line, you should use the rule-of-thumb method; use the formula when the values that must be substituted in it are known.

a. Rule of thumb. When the planner does not know the number or location of passing tracks, the length of the line, or the average speed at which trains can be operated safely over the line, he uses the following rule of thumb for train density: on single-track lines a TD of 10 and on double-track lines a TD of 30 is established.

b. Formula for determining single-track train density. In a theater of operations, one track of most double-track lines is cannibalized to maintain one good single track. Cannibalize means to remove serviceable parts from one item of equipment to install them on another. The discussions in this text are confined to single-track operations. The following formula may be used to determine fairly accurately the TD for a specific single-track railway division if the factors included in it are known.

$$TD = \frac{NT + 1}{2} \times \frac{24 \times S}{LD}$$

Where

TD = train density

NT = number of passing tracks

1 = constant (number of trains that could be run if there were no passing tracks)

2 = constant to convert to one direction

24 = constant (number of hours per day)

S = average speed

LD = length of division

An example of how to use the formula to determine train density is presented in the next paragraph. It is based upon pertinent information on a hypothetical railway division.

2.14. EXAMPLE OF TRAIN DENSITY DETERMINATION

You are going to operate a single-track rail division of 110 miles with a ruling grade of 1.3 percent and track rated good to fair. Passing tracks are located at the following distances in miles from the beginning of the division: 7, 15, 21, 27, 31, 37, 45, 53, 60, 66, 74, 81, 85, 91, 97, and 103. With this information and the formula you can find values for each of the unknowns and determine the train density. The following subparagraphs discuss each unknown and illustrate how it is used.

<u>a</u>. <u>Number of passing tracks (NT)</u>. As stated earlier, passing tracks should be at intervals of 6 to 8 miles along the main line. A passing track within 5 miles of another one should not be counted when determining TD because two passing tracks that close together do not increase TD. In the formula, the value you should substitute for NT for this hypothetical division is 14. Notice that this value is two less than the number of passing tracks given; but, two of them, those at mileposts 31 and 85, are within 5 miles of the tracks immediately preceding them and should not be counted.

<u>b</u>. <u>Average speed (S)</u>. Table IV presents average speed values for different conditions of track and percentages of ruling grade. Experience with previous military railway operations has proved these factors to be accurate enough for determining TD. You know that your division is rated good to fair and that the ruling grade is 1.3 percent. From the table you determine that the average speed of trains for a single-track rail line rated good to fair with a ruling grade of 1.5 percent or less is 10 mph. Remember that the most restrictive factor is used to govern the selection of the average speed. For example, if the track was rated good to fair but the ruling grade was 2.0 percent, the grade factor would be the most restrictive and the average speed would be 8 mph.

Table IV. Determining Average Speed Values

Track	Percent of ruling grade	Average speed (mph)	
		Single track	Double track
Exceptionally good	1.0	12	14
Good to fair	1.5 or less	10	12
Fair to poor	2.5 or less	8	10
Poor	3.0 or less	6	8

c. Length of division (LD). You know that your division is 110 miles long; therefore, the value for LD in the formula is 110.

d. Using the TD formula. Now that you have a value to substitute for each of the unknowns, your formula develops as follows:

$$TD = \frac{NT + 1}{2} \times \frac{24 \times S}{LD}$$

$$TD = \frac{14 + 1}{2} \times \frac{24 \times 10}{110}$$

$$TD = \frac{15}{2} \times \frac{240}{110}$$

$$TD = \frac{3,600}{220}$$

$$TD = 16.3+, \text{ or } 17.$$

Once you know what each locomotive can pull, the amount of freight or payload that can be moved on each train, and the number of trains you can run each day, you determine the net division tonnage, as explained in the next paragraph.

2.15. NET DIVISION TONNAGE

The tonnage or payload, expressed in short tons, that can be moved over any division each day is the net division tonnage (NDT).

The NDT includes railway operating supplies which must be programmed for movement the same as the supplies of any other service. The NDT is computed separately for each division of rail line; it is determined by multiplying the net trainload by the train density. For example, if the NTL for a division is 383 STON and the TD is 17, the estimated NDT is 6,511 STON:

383 x 17 = 6,511

However, this estimate is valid only if all 17 trains are freight trains. If other types of trains such as passenger, troop, or hospital trains are used, they will replace an equal number of freight trains. When the operation of such trains is anticipated, allowance in the NDT estimates is made by adjusting the TD of the division. For example, if 4 passenger trains are scheduled for this division, or if their need is anticipated, the estimated NDT is adjusted by multiplying 383 by 13, since you would be running only 13 freight trains. The adjusted NDT is 4,979 short tons.

2.16. END DELIVERY TONNAGE

The final step in rail line capacity determination, and the estimation you as a planner have been trying to make, is end delivery tonnage (EDT). The EDT is the number of short tons of through freight that can be delivered at the end of the rail line (railhead) each day. This determination is most important to the planner, because it is this freight that supports the combat forces in the forward areas of a theater. In an all-rail movement, where freight is delivered exclusively by rail, the EDT is the same as the net division tonnage (NDT) of the most restrictive division of the entire railroad. For example, if the NTL for each division of a three-division railroad is 383 short tons and the train densities are 10, 9, and 11, the NDT's are 3,830, 3,447, and 4,213 respectively. The EDT for this railroad is 3,447 short tons. The second division is the most restrictive because it has the lowest train density--9.

2.17. EXAMPLE OF RAILWAY LINE CAPACITY DETERMINATION

For a practical application of the information found in this chapter, an example is presented of how to determine the tonnage capacity of a hypothetical three-division, single-track, standard-gage rail line in a theater of operations. Extending from a port to a railhead, it has a port terminal, two division terminals, and an unloading terminal at the railhead. Assume that you are the planner, and you have the following intelligence information about each of the three divisions. Your problem is to determine the end delivery tonnage at the railhead, or end of the rail line.

a. First division.

Length of line......................105 miles.
Track...............................Good to fair.
Percent of ruling grade.............1.5.
Ruling curve........................2.5°.
Temperature (lowest expected)........0° to +15°
Motive power........................0-6-6-0 diesel-electric, 127-ton road locomotives. (Use data in table I).
Number of effective passing tracks..............................12.

b. Second division.

Length of line......................10 miles
Track...............................Good to fair.
Percent of ruling grade.............1.8.
Ruling curve........................5°.
Temperature (lowest expected)........-1° to -10°.
Motive power........................0-4-4-0, diesel-electric, 120-ton locomotives, drawbar pull 33,600 pounds each.
Number of effective passing tracks..............................6.

c. Third division.

Length of line......................96 miles.
Track...............................Good to fair.
Percent of ruling grade.............1.2.
Ruling curve........................3°.
Temperature (lowest expected)........0° to +15°.
Motive power........................Same as first division.
Number of effective passing tracks..............................11.

Because the end delivery tonnage is the same as the net division tonnage of the most restrictive division, you must determine the NDT for each division.

2.18. FIRST DIVISION NDT

The first step in determining the NDT for the first division is to find the starting tractive effort of the locomotives you have.

a. Tractive effort. Table. I shows that the 0-6-6-0, 127-ton diesel-electric locomotive has a starting tractive effort of 75, 700 pounds. The continuous tractive effort for this locomotive is 50 percent of its starting tractive effort, or 37,850 pounds. Your second step is to find drawbar pull.

b. Drawbar pull. The locomotives weigh 127 short tons each. Subtract 20 pounds per ton of total locomotive weight from the continuous tractive effort and you have the drawbar pull of each locomotive:

$$20 \times 127 = 2{,}540$$

$$37{,}850 - 2{,}540 = 35{,}310 \text{ DBP}$$

c. Gross trailing load. The third step is to find the gross trailing load for the locomotives. To use the formula for GTL presented in paragraph 2.10, you must find the values for each unknown. You already have a value for DBP; therefore, concentrate on weather, rolling resistance, grade resistance, and curve resistance. The process for finding values for each of these follows in the order mentioned.

(1) Weather. Using table III and the information given on the first division, you find that the loss in hauling power between 0° and +15° F. is 10 percent; therefore, the value for the weather factor (W) is 0.90.

(2) Rolling resistance. Since the track for the first division is rated good to fair, table II shows that a value of 6 should be used for rolling resistance (RR).

(3) Grade resistance. Multiply 20 pounds per ton of train by the percent of ruling grade for this division (1.5) and you find that the value for grade resistance (GR) is 30.

(4) Curve resistance. The ruling curve for this division is 2.5°, which must be multiplied by 0.8 pounds per ton of train to get the value for curve resistance (CR) of 2.

(5) Using the formula. Now that you have values for all of the unknowns, substitute them in the formula for CTL, as illustrated in subparagraph 2.11f, and make the necessary computations.

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

$$GTL = \frac{35,310 \times .90}{6 + 30 + 2}$$

$$GTL = \frac{31,779}{38} = 836+, \text{ or } 837 \text{ STON}$$

d. Net trainload. The fourth step is to find the net trainload (NTL) as explained in paragraph 2.12. Since NTL is 50 percent of GTL, the NTL for this division is 419 short tons.

837 x .50 = 418+, or 419 short tons

e. Train density. Now, for the fifth step, determine what the train density (TD) is for the division. Using the formula presented in paragraph 2.13b and the information in paragraph 2.17a, you have values for all of the unknowns except average speed (S). Since the track is rated good to fair and the percent of ruling grade is 1.5, table IV shows that an average speed of 10 mph should be used. Substitute this value in the formula and make your computations for TD as follows:

$$TD = \frac{12 + 1}{2} \times \frac{24 \times 10}{105}$$

$$TD = \frac{13}{2} \times \frac{240}{105}$$

$$TD = \frac{3,120}{210}$$

$$TD = 14+, \text{ or } 15$$

f. Net division tonnage. Now that you know the NTL and the TD for this division, the final step is to find the net division tonnage (NDT) by multiplying the two values NTL x TD:

419 x 15 = 6,285 STON

If you do not run any passenger trains over this division, you can move 6,285 short tons over it.

2.19. SECOND DIVISION NDT

The discussion of the NDT for the remaining two divisions is much briefer; however, the necessary computations are presented for you to follow.

The drawbar pull of the 0-4-4-0 diesel-electric locomotives used on the 2d division is given as 33,600 pounds in paragraph 2.17b, Therefore, the first computation is for gross trailing load (GTL).

$$DBP = 33{,}600$$

$$W = .85$$

$$RR = 6$$

$$GR = 36$$

$$CR = 4$$

$$GTL = \frac{33{,}600 \times .85}{6 + 36 + 4}$$

$$GTL = \frac{28{,}560}{46}$$

$$GTL = 620+, \text{ or } 621 \text{ STON}$$

The second computation is for net trainload (NTL)

NTL = 50% of GTL

NTL = .50 x 621

NTL = 310+, or 311 STON

The third computation is for train density (TD).

$$NT = 6$$

$$S = 8$$

$$LD = 110$$

$$TD = \frac{6 + 1}{2} \times \frac{24 \times 8}{110}$$

$$TD = \frac{7}{2} \times \frac{192}{110}$$

$$TD = \frac{1,344}{220}$$

$$TD = 6+, \text{ or } 7$$

The final computation is for net division tonnage (NDT).

NDT = TD x NTL

NDT = 7 x 311

NDT = 2,177 STON

2.20. THIRD DIVISION NDT

The motive power used for the third division is the same as that on the first division; therefore, you begin your computations with GTL.

DBP = 35,310

W = .90

RR = 6

GR = 24

CR = 2.4

$$GTL = \frac{35,310 \times .90}{6 + 24 + 2.4}$$

$$GTL = \frac{31,779}{32.4}$$

GTL = 980+, or 981 STON

The second computation is for net trainload (NTL).

NTL = GTL x 50%

NTL = 981 x .50

NTL = 490+, or 491 STON

The third computation is for train density (TD)

$$NT = 11$$

$$S = 10$$

$$LD = 96$$

$$TD = \frac{11 + 1}{2} \times \frac{24 \times 10}{96}$$

$$TD = \frac{12}{2} \times \frac{240}{96}$$

$$TD = \frac{2{,}880}{192}$$

$$TD = 15$$

The final computation for the third division is for the net division tonnage (NDT).

NDT = TD x NTL

NDT = 15 x 491

NDT = 7,365 STON

2.21. END DELIVERY TONNAGE FOR THE LINE

Now that you have found the net division tonnage for all three divisions (1st division--6,285 short tons; 2d division--2,177 short tons; 3d division--7,365 short tons), you know that the end delivery tonnage (EDT) is the same as that of the net division tonnage of the most restrictive division--the 2d division with 2,177 short tons.

2.22. METHODS OF ADJUSTING EDT

If you were planning an actual railway operation similar to the one presented in paragraphs 2.17 through 2.21, you would want to examine the weak division to see if the net division tonnage could be increased so that the EDT could be raised. The 2d division in the example has a very low NDT in relation to the other two divisions. It can be increased either by double-heading the locomotives or by constructing more passing tracks. Each of these methods is discussed in the following subparagraphs.

a. Double-heading locomotives. If there are enough 0-4-4-0 diesel-electric locomotives on the 2d division, they can be double-headed. Since diesels can be double-headed without loss of hauling power, the GTL can be doubled as can the NTL. With the same TD, the NDT is adjusted to 4,347 short tons. As a result, the EDT is correspondingly increased.

621 STON	= GTL of the 0-4-4-0 locomotives used on the the 2d division
x 2	= number of locomotives (double-headed)
1,242 STON	= adjusted GTL for the 2d division

1,242 STON	= adjusted GTL for the 2d division
x .50	= percent of GTL that is NTL
621.00 STON	= adjusted NTL

621 STON	= adjusted NTL
x 7	= TD of the 2d division
4,347 STON	= adjusted NDT

Since the 2d division would still be the most restrictive of the three divisions with an NDT of 4,347 short tons, the EDT for the railroad would also be 4,347 short tons.

b. Increasing the number of passing tracks. If you cannot double-head locomotives but you can increase the number of passing tracks by constructing new ones at proper locations, from 6 to 8 miles from other passing tracks, the train density can be increased. For example, by constructing 6 new passing tracks, thereby increasing the TD to 12, the NDT for the second division can be raised to 3,732 short tons. Again the EDT is correspondingly raised.

311 STON	= NTL for the 2d division
x 12	= adjusted TD for the 2d division
622	
311	
3,732 STON	= adjusted NDT for the 2d division

The adjusted NDT of 3,732 short tons for the 2d division would be the EDT for the railroad, because this division would still be the most restrictive of the three divisions.

2.23. SUMMARY

To determine the tonnage capacity of a rail line, a planner must know the work capacity or hauling power of the locomotives he intends to use. The entire potential force or power of the locomotive, known as tractive effort and expressed in pounds, cannot be used solely for hauling freight; some of it is used to move the locomotive. The tractive effort of a locomotive is generally included in the data supplied by the manufacturer; however, when it is not known, military planners compute it by a rule of thumb whereby 25 percent of the locomotive's weight on drivers is its starting tractive effort.

Starting tractive effort is the power of a locomotive to move itself and the load it is hauling from a stopped position. Continuous tractive effort is the effort required to keep a train rolling after it has been started. No distinction is made between starting and continuous tractive effort in a steam locomotive because it can generally continue to pull what it can start. However, a diesel-electric locomotive cannot continue to exert maximum starting power without damaging its traction motors. Therefore, the continuous tractive effort of a diesel-electric locomotive is approximately one-half of its starting tractive effort.

In determining tractive effort, an understanding of the Whyte classification system is essential to the planner because tractive effort is directly affected by the amount of a locomotive's weight that rests on its driving wheels. The Whyte system, used by the Army to classify its locomotives, identifies the wheel arrangements by symbols and indicates the number of driving wheels.

Certain reductions in the locomotive's power affect the tonnage capacity of a rail line. The first reduction, caused by the need to move the locomotive itself, comes when calculating drawbar pull. By subtracting 20 pounds per ton of total locomotive weight from the continuous tractive effort you find the actual pulling ability of the locomotive or its drawbar pull. Other reductions in the locomotive's power are: rolling, grade, and curve resistance expressed in pounds per ton of train, and reduced efficiency of the locomotive in bad weather. The weather factor is expressed in percent.

After making allowances for reductions in the locomotive's potential power, the next thing a planner must do is to find out the maximum weight or load that the locomotive can safely pull behind it. This is known as gross trailing load and is expressed in short tons. It includes both the weight of the cars and the freight in them. Remember that when double-heading trains or using pushers, add the GTL of each locomotive and then multiply the total by 90 percent for steam locomotives and 100 percent for diesels.

The next step is to determine the net trainload--the weight of the payload or freight carried by a train. Military planners use a value of 50 percent of the gross trailing load to determine NTL.

Train density, the number of trains that can be safely operated over a rail division in each direction during a 24-hour period, may vary with each division of rail line, depending on the characteristics of each. If enough intelligence data on the rail line are available, the planner uses a formula that takes into account the number of passing tracks, average speed, and length of division in determining train density. However, in the absence of sufficient information, military planners use the rule of thumb which allows a TD of 10 for single-track and 30 for double-track lines.

The next thing a planner figures is net division tonnage--the tonnage or payload in short tons that can be moved over a rail division each day. Computed separately for each division of rail line, NDT is found by multiplying the net trainload by the train density for each division.

The final step in determining rail line capacity is the end delivery tonnage, or the through tonnage of payload that can be delivered at the railhead each day. In an all-rail movement, the end delivery tonnage is the same as the NDT of the most restrictive division of the railroad.

Once the tonnage capacity of a rail line has been determined, the next thing a planner needs to know is how to determine the amount and types of equipment required to operate the railroad at maximum capacity.

Chapter 3

EQUIPMENT REQUIREMENTS

3.1. GENERAL

An essential part of a rail planning job is to determine the amount of equipment required for the operation. To a military planner, railway equipment falls into three categories: rolling stock, consisting of boxcars, gondolas, flatcars, tank cars, and refrigerator cars; road engines, the motive power used to pull trains over main lines between terminals or division points; and switch engines, the motive power used to switch cars within yards and at division terminals. Each category and how to determine how much of each is required for a rail operation is explained separately in paragraphs 3.3 and 3.4. The following paragraph discusses where rail equipment comes from and how it is obtained.

3.2. AVAILABLE EQUIPMENT

Equipment in liberated or occupied territory that may be used by the TRS depends on the extent of destruction or damage and types and availability of fuel and spare parts. The planner may find technical data on rail equipment in a theater in logistical surveys, special transportation studies based on intelligence reports, reports of governments and privately owned railways produced during peacetime, and articles appearing in such publications as the British Railway Gazette and the United States Railway Age.

The U.S. Army owns railway equipment to be used by the TRS in a theater of operations when required. The types and characteristics of some of the motive power are given in table I in the preceding chapter; table V lists those of rolling stock. Whenever a planner cannot determine how much equipment is on hand for his use in a theater, he should plan to use equipment as listed in these two tables.

Table V. Characteristics of U.S. Army Rolling Stock

Type of car	Gage	Capacity tons	Tare weight (empty tons)	Inside dimensions		
				Length	Width	Height
I. Foreign Service						
Box (30-ton)	Narrow	30	13.6	34' 5 1/2"	7' 3/4"	6' 4"
Box (40-ton)	Std to broad	40	18.5	40' 6"	8' 6"	6' 5 3/4"
Flat (30-ton)	Narrow	30	10.9	34' 5 7/8"	7' 2"	
Flat (40-ton)	Std to broad	40	14.5	40' 9"	8' 7 1/4"	
Flat (80-ton)	Std to broad	80	35.3	46' 4"	9' 8"	
Flat, depressed center (70-ton)	Std to broad	70	41.5	50' 7"	9' 8"	
Gondola, high side (30-ton)	Narrow	30	13	34' 5"	6' 10 1/2"	4' 0"
Gondola, high side (40-ton)	Std to broad	40	18	40' 0"	8' 3 3/4"	4' 0"
Gondola, low side (30-ton)	Narrow	30	12.1	34' 6"	6' 10 1/2"	1' 6"
Gondola, low side (40-ton)	Std to broad	40	16	40' 4 1/2"	8' 3 1/4"	1' 6"
Tank, POL (6,000 gal)	Narrow	20	10			
Tank, POL (10,000 gal)	Std to broad	35	19			
II. Domestic Service						
Box (50-ton)	Std	50	23	40' 6"	9' 2"	11' 0"
Flat (50-ton)	Std	50	25.5	43' 3"	10' 6"	
Flat (70-ton)	Std	70	27	49' 11"	10' 3"	
Flat (100-ton)	Std	100	35	54' 0"	10' 6 1/2"	
Gondola, high side (50-ton)	Std	50	25	41' 6"	9' 6"	4' 6"
Gondola, low side (50-ton)	Std	50	23	41' 6"	9' 6"	3' 0"
Tank, POL (10,000 gal)	Std	50	23			

NOTE: Average payload for each type of car except tank cars, is 50 per cent of the rated capacity.

3.3. ROLLING STOCK

When planning for rolling stock, a planner thinks in terms of the types and numbers of railway cars required to move freight. In most military operations, freight movement is in one direction only, from a port or base depot to a railhead in the forward area of a theater. Occasionally freight may be moved from a port to a point on the same division and unloaded, and different freight picked up there and moved on forward by the same train. This kind of freight movement is commonly referred to as a setout and fill-out operation. However, the net division tonnage remains approximately the same. Regardless of the kind of operation, there must be enough cars to maintain continuity of car loadings and movements. How many are enough? The following paragraph explains how to make an estimate of rolling stock requirements accurately enough for broad planning purposes.

3.4. ESTIMATING ROLLING STOCK REQUIREMENTS

Each railway car has a rated capacity, normally stenciled on its side, given in pounds. For example, a boxcar with 80,000 stenciled on its side has a rated capacity of 80,000 pounds or 40 short tons. However, for planning purposes, the carrying capacity or average payload of that car is 40,000 pounds (20 short tons) or 50 percent of its rated capacity. There is a good reason for using only half of the rated capacity of cars in planning. If you packed a boxcar full of lightweight bulky cargo such as blankets, the payload would weigh far less than the rated capacity. If, however, you packed the car with ammunition, the payload weight would be much nearer or might even exceed the rated capacity. Therefore, a good average figure to use for payload in planning is 50 percent or one-half the rated capacity of all freight cars except tanks cars. The capacity in gallons and tons is stenciled on their sides. If a tank car holds 10,000 gallons of water it will hold 10,000 gallons of any other liquid, and it can be loaded to its content capacity if the weight of the liquid does not exceed the maximum tonnage capacity of the car. Use the rated capacity for tank cars.

Once you know the average payload of the cars you have, you must find the number of cars needed to transport the end delivery tonnage. This is referred to as 1 day's dispatch (DD), or the number of cars dispatched from the port or base of operations in a day. It is also the number of cars that run over the first division each day. In broad planning, 1 day's dispatch is considered the same for all divisions of railroad between the port and the railhead. Also, all divisions are assumed to have the same train density and the same

number of cars per train, because the bulk of all cargo moved in a theater is through freight--from port to railhead.

To find the number of cars, by type, required for 1 day's dispatch, divide the number of short tons to be transported in each type of car by the average payload of these cars. An example of how to determine 1 day's dispatch is given in paragraph 3.5.

When you know the number of cars in 1 day's dispatch, you can determine the total number of cars required for the entire operation. To do this, you must first know the turnaround time, the total estimated number of days required from the time a car is placed for loading at its origin, moved to its destination, unloaded, and returned to its origin. Such time is computed as follows: allow 2 days at origin, 2 days' transit time for each division (1 for forward and 1 for return traffic), and 1 day at destination. This method, rather than an actual hourly basis, is used to allow for delays due to switching at terminals and way stations and rehandling of trains in transit. The total number of cars required for the operation is determined by multiplying 1 day's dispatch of each type of car by the turnaround time. Then, to the total number required, add 10 percent to each type of car as a reserve to allow for contingencies such as routine maintenance, bad order cars, operational peaks, and delays.

3.5. EXAMPLE OF DETERMINING ROLLING STOCK REQUIREMENTS

Assume that you are planning a rail operation in a theater of operations. The railroad is the same hypothetical three-division, single-track, standard-gage rail line discussed in paragraph 2.17 of chapter 2. You are not double-heading or adding more sidings. The line reaches from a port to a railhead in the forward area of the theater. You have already determined that the end delivery tonnage for the railroad is 2,177 short tons. From your intelligence data you find that the tonnage is to be moved on the following basis: 50 percent of the EDT will be shipped in boxcars, 40 percent in gondolas, and 10 percent in flatcars. The three types of cars are all U. S. Army rolling stock with rated capacities of 40 short tons, or carrying capacities (payload) of 20 STON each. Your problem is to find how many cars, by type, are required to operate the railroad.

First, you must find a value for 1 day's dispatch (DD). This computation is important, because subsequent switch engine requirements are based on 1 day's dispatch. Remember that in broad planning, 1 DD is considered the same for all divisions of the railway in operation.

To find the number of cars by type for 1 day's dispatch, first multiply the EDT by the percent of EDT to be hauled in each type of car. Then divide the result by the carrying capacity (payload) of the cars. For example:

EDT x percent	=	tons by type	÷	car capacity	=	DD
2,177 x .50	=	1,089 STON in boxcars	÷	20 STON	=	55
2,177 x .40	=	871 STON in gondolas	÷	20 STON	=	44
2,177 x .10	=	218 STON in flatcars	÷	20 STON	=	11
		1 DD of all cars				110

Therefore, you find that 1 day's dispatch consists of 55 boxcars, 44 gondolas, and 11 flatcars, a total of 110 cars.

When you find the value for 1 day's dispatch, your next step is to determine how many cars are required to move the EDT every day. To find this number, multiply 1 DD of each type of car by the turnaround time, and add a 10 percent reserve. The turnaround time for this hypothetical railroad, as shown in figure 3.1, is 9 days. Your calculation should be as follows:

	DD	x	TAT		RF
Boxcars	55	x	9	= 495; 495 x .10*	= 49+, or 50
Gondolas	44	x	9	= 396; 396 x .10	= 39+, or 40
Flatcars	11	x	9	= 99; 99 x .10	= 9+, or 10

	495 + 50 =	545
	396 + 40 =	436
	99 + 10 =	109
Total rolling stock required		1,090

---

*Whenever you have to add a reserve factor, you can eliminate one step in your computations by multiplying by the following equivalents

5% = 1.05
10% = 1.1

20% = 1.2

Instead of this: 495 x .10 = 49+ or 50 495 + 50 = 545.
Do this: 495 x 1.1 = 544+ or 545.

Your rolling stock requirements to operate the railroad are 545 boxcars, 436 gondolas, and 109 flatcars, or a grand total of 1,090 cars. Now you must determine how many road engines are required to pull them over the railroad.

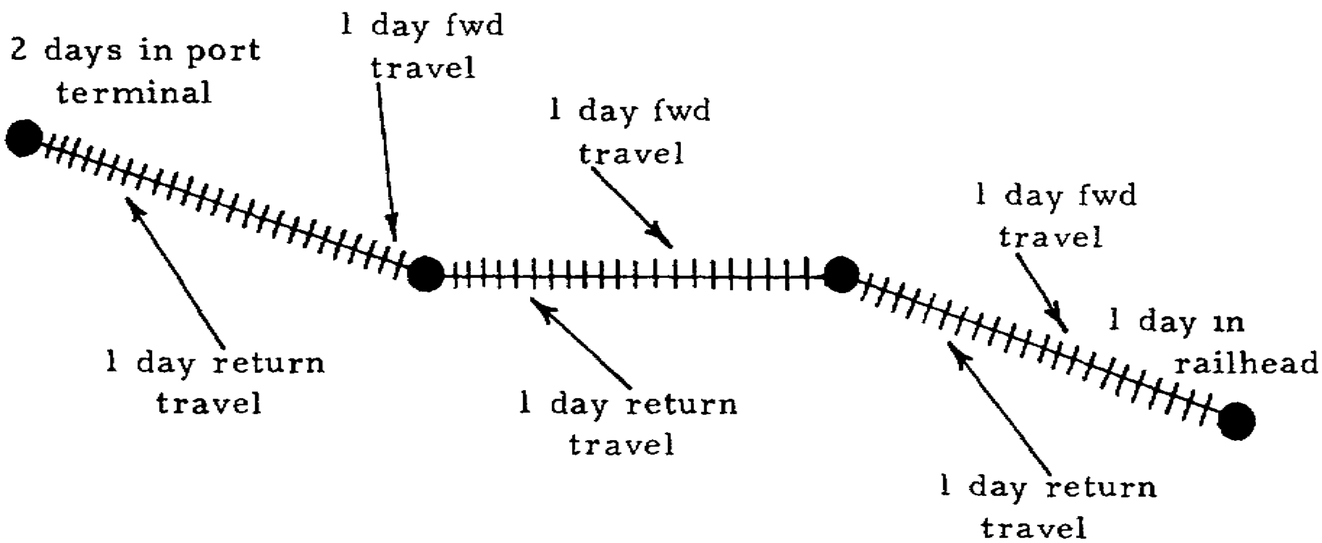


Figure 3.1. Determining Turnaround Time.

3.6. ROAD ENGINES

The number of road engines required for any given railway division may be found by using the following formula.

$$\text{Road engines required} = TD \times \frac{RT + TT}{24} \times 2 \times 1.2$$

where TD = Train density

RT = Running time

TT = Terminal time

24 = Number of hours per day

2 = Constant for two-way traffic

1.2 = Constant allowing 20 percent reserve

The expression $\frac{RT + TT}{24}$ in the formula is known as the engine factor; it represents the percent of time during a 24-hour period that a road engine is in use. It provides for the pooled use of

motive power that may make one or more trips per day over a short division.

The three unknowns in the formula are TD (train density, found as explained in paragraphs 2.13 and 2.14); RT (running time, found by dividing the length of the division by the average speed); and TT (terminal time, found by using table VI). Terminal time is that time required for servicing and turning locomotives.

Table VI. Terminal Time Average Values

Type of motive power	Hours
Diesel-electric	3
Steamed-powered	8

The number of road engines required must be computed for each division separately. A detailed explanation of how to determine the road engine requirements is presented in the following paragraph.

3.7. EXAMPLE OF DETERMINING ROAD ENGINE REQUIREMENTS

The division of railroad used in this example is the 110-mile second division given in the example in paragraphs 2.17 and 2.19. It has a train density of 7, and the track is rated good to fair with a ruling grade of 1.8 percent. The motive power used for road service on this division is 0-4-4-0 diesel-electric locomotives.

Since a value for TD in the formula is known, you must find values for RT and TT. The length of the division (110 miles) divided by the average speed gives you the value of RT. Look at table IV. An average speed of 10 mph is given for a good to fair track with a ruling grade of 1.5 percent or less. However, the ruling grade for this division is 1.8 percent; therefore, the more restrictive factor of 2.5 governs. The average speed, then, is 8 mph. The value for RT is 14.

$$110 \div 8 = 13+ \text{ or } 14$$

Now look at table VI, which shows that the terminal time (TT) for diesel-electric locomotives is 3 hours. The value to be substituted in the formula for TT is, therefore, 3. The computation for road engines is made as follows:

$$\text{Road engines required} = TD \times \frac{RT + TT}{24} \times 2 \times 1.2$$

$$= 7 \times \frac{14 + 3}{24} \times 2 \times 1.2$$

$$= \frac{285.6}{24}$$

$$= 11+, \text{ or } 12$$

Following the same procedure for the other two divisions, you find that the first division requires 21 road engines and the third division 20. By totaling the requirements of the three divisions, you get the number of road engines needed to operate the railroad.

12 + 21 + 20 = 53

3.8. SWITCH ENGINES

The third and final category of railway equipment that must be planned for is switch engines. They are used in yards to move railway cars that are received, classified, and reassembled for departure. No two yards are the same size or have the same type and scope of operation; however, the functions of the main yards on any railroad are essentially the same.

The number of switch engines required at a terminal is based on the number of cars received at, dispatched from, or passing through it per day. When the number of cars has been computed, that number should be applied to table VII to compute the number of switch engines required at each terminal. For example, in the explanation of how to determine rolling stock requirements in paragraph 3.5, 220 cars pass through each division terminal each day (110 forward and 110 return traffic), not counting the 10 percent or 242 cars in the reserve. However, you do not include the reserve when calculating the number of switch engines needed. Table VII shows that you need one switch engine for every 100 cars passing through a division terminal each day; therefore in the example, you need 3 switch engines

220 + 100 =2+, or 3

for each division terminal. You also need 4 at the port

220 + 67 = 3+, or 4

and 4 at the railhead. Thus far, your switch engine requirements should look like this:

4	at the port terminal
3	at the 2d division terminal
3	at the 3d division terminal
4	at the railhead
14	subtotal

To get the total required for the entire railroad, you must add 20 percent to the subtotal to allow a reserve for maintenance and operational peaks.

14 x .20 = 2.80+ or 3; 14 + 3 = 17

Table VII. Disposition of Switch Engines

Location	Switch engines required
Port or loading terminals	1 per 67 cars dispatched and received per day
Division terminals	1 per 100 cars passing per day
Railhead or unloading terminals	1 per 67 cars dispatched and received per day

3.9. SUMMARY

The three types of equipment that must be included in a rail plan are rolling stock, road engines, and switch engines. The question is, how many of each type will be required for a particular operation?

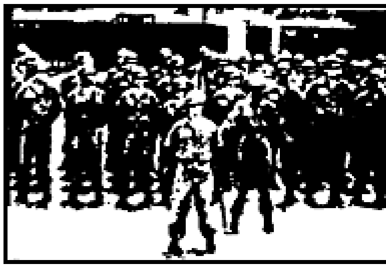
The number of cars (rolling stock) needed is based on 1 day's dispatch. Remembering that the payload of a car is 50 percent of its rated capacity, you find 1 day's dispatch by multiplying the end delivery tonnage by the percent of the gross division tonnage to be carried in each type of car, then by dividing the result by the payload of the cars. This gives the number of cars by type for 1 day's

dispatch. When you multiply this number by the turnaround time and add to the product 10 percent to allow a reserve for contingencies, you get the total number of cars, by type, required for the entire operation.

Road engine requirements are computed separately for each division by multiplying the TD by the engine factor and then multiplying by 2 for two-way traffic and finally by 1.2 to provide a 20 percent reserve. When the number of road engines required for each division is known, the total of these is the number required for the whole rail operation.

The number of switch engines required at a division terminal is one for every 100 cars passing through the terminal each day; at port or loading terminals and at railhead or unloading terminals, the requirements are one for every 67 cars dispatched and received per day. Once the number of switch engines needed at each division terminal, at the port, and at the railhead is known, the total plus 20 percent is the switch engine requirement including the reserve factor for the entire rail operation.

When the planner knows how much equipment is needed, he must determine how many people are required to operate it. The following chapter explains how to determine personnel requirements.



Chapter 4

PERSONNEL REQUIREMENTS

4.1. GENERAL

Thus far, the discussions in this text explain how the rail transportation planner obtains information and how he uses it to determine the capacity of a railroad and the amount of equipment required to operate it. The planner's next job is to determine how many people are needed for the rail operation. The methods for determining the number of road crews, switch crews, and subsequently the number and kind of rail units required are explained in this chapter.

4.2. ROAD CREWS

The number of road crews needed for each division is based on the amount of time each crew works and the rest time each crew requires. Work time includes a 2-hour call period, the running time, and a 1-hour period at destination. Normally, crews should have 12 hours off before reporting back on duty. The 2-hour call period is necessary at the originating terminal of the division for crews to report for duty, receive orders and instructions, move a locomotive from the roundhouse to the departure yard, couple it to a train, test the airbrake system, and check the train consist. The running time (RT) is the length of time it takes to run the train over the division. It is computed as stated in paragraph 3.6, by dividing the length of the division by the average speed of the train. If the average speed is not known, the planner should assume it to be 8 mph for a single-track operation in a theater and 10 mph for a double-track operation. Another time factor that must be included in the computation is the 1-hour period at the final destination. It allows for placing the train on designated tracks, moving the locomotive to the roundhouse, and submitting the necessary reports.

Normally the sum of the call period, the running time, and the 1-hour period at the final destination should not exceed 12 hours so that crews have sufficient time to rest before reporting back on duty. The 12-hour time limit can be exceeded for short periods in

emergencies; however, experience has proved that both safety and efficiency decrease when crews must work continuous daily shifts of more than 12 hours. It is possible to work crews on 16-to 18-hour shifts provided that sufficient rest periods are allowed before they report back on another run. Road crews may be required to work longer shifts because of the length of the division. When they are, they should be allowed enough time off between runs so that the daily shift will not average more than 12 hours.

The following paragraph presents and explains a formula that military planners use to obtain a fairly accurate determination of the number of road crews needed for a given railway division.

4.3. FORMULA FOR DETERMINING ROAD CREWS

To determine the number of road crews needed for a rail division, find values for the unknowns and substitute them in the following formula:

$$\text{Number of road crews} = TD \times 2 \times \frac{RT + 3}{12} \times 1.25$$

where:

TD = train density

2 = factor to convert to two-way traffic

RT = running time (length of division divided by average speed)

3 = time allowed for 2-hour call period plus 1-hour period at destination

12 = 12-hour shift per road crew per day

1.25 = constant factor to allow 25 percent reserve for sickness and other absences

If you are going to operate a single-track rail division 90 miles long with a TD of 10 and an average speed of 10 mph, you can use the formula and determine the number of road crews you need as follows:

$$\text{Number of road crews} = TD \times 2 \times \frac{RT + 3}{12} \times 1.25$$

$$= 10 \times 2 \times \frac{9 + 3}{12} \times 1.25$$

$$= 20 \times \frac{9 + 3}{12} \times 1.25$$

$$= 20 \times \frac{12}{12} \times 1.25$$

$$= \frac{240}{12} \times 1.25$$

$$= \frac{300}{12} \text{ or 25 road crews required}$$

4.4. SWITCH CREWS

In addition to crews necessary to operate the trains over main lines, you must have switch crews to operate the switch engines and perform switching service in the yards and terminals of the railroad. The number of these crews required is based upon the number of switch engines in use at each yard and terminal. The method of determining the needed number of switch engines is explained in paragraph 3.8 of chapter 3. Once you know that number, substitute it in the following formula.

Number of switch crews = SE x 2 x 1.25

where:

SE = number of switch engines

2 = two crews per engine

1.25 = constant factor to allow for sickness and other absences.

For planning purposes, two switch crews are needed for each switch engine per day. Do not include switch crews for the reserve switch engines. For example, in paragraph 3.8 we found that three switch engines are required for each hypothetical division terminal not including the reserve factor. In computing the number of switch crews needed at each terminal, the computation is made as follows:

Number of switch crews = SE x 2 x 1.25

= 3 x 2x 1.25

= 6x 1.25

Number of switch crews = 7+ or 8

The number of switch and road crews required determines how many rail units are needed.

4.5. RAILWAY UNITS REQUIRED

The number and kind of TRS units a rail operation requires are based principally on the number of transportation railway battalions necessary. In turn, the number of TRB's required depends on the number of traincrews, both road and switch, needed. The following subparagraphs explain the basis for reassignment and capabilities of transportation railway service units.

a. The transportation railway battalion can provide 40 traincrews daily through its attached train operating company. Each crew can work as either a switch or a road crew. Normally, one TRB is assigned for each railway division to be operated; however, if there is an exceptionally large yard and terminal on the railroad, an additional TRB is generally assigned to operate it.

To determine the number of railway battalions that should be assigned, the total number of road and switch crews required for the entire line is divided by 40 (number of crews provided daily per TRB). The number of divisions into which the line is divided, however, may affect the number of TRB's. For example, if you are going to operate a three-division railroad and you need 120 crews, three TRB's are assigned. If you need 140 crews for the same three divisions, however, the normal assignment would still be three battalions, with the additional 20 crews (140 -120 = 20) assigned through augmentation with transportation railway service teams authorized by Table of Organization and Equipment (TOE) 55-520. On the other hand, if the line were divided into four divisions and 150 crews were required, four TRB's would be assigned to operate it. The kind of operation and the length and number of divisions determine the cutoff point for augmentation and the assignment of an additional TRB.

b. The transportation railway group (TRG), a supervisory and administrative unit, is normally the senior TRS organization in

the theater. Railway groups are assigned on the basis of one per two to six transportation railway battalions.

c. The transportation railway brigade is assigned to supervise a very large TRS operation where three or more transportation railway groups are required. However, the rail operation is seldom large enough to require this level of supervision.

4.6. EXAMPLE OF DETERMINING TRS UNITS REQUIRED

Assume that you are going to operate a five division railroad and you need 215 crews. You must determine the number of TRS units needed to operate the rail line. The first step is to divide 215 (crews required) by 40 (crews provided daily per TRB). The normal assignment would be five TRB's with the 15 additional crews assigned through augmentation authorized by TOE 55-520. One railway group would be required to supervise the operation.

4.7. SUMMARY

The number of transportation railway service personnel required to operate a military railroad in a theater of operations depends primarily on the number of railway battalions needed. The number of TRB's required is based on the number of road and switch crews needed to operate the entire railroad. The amount of working time necessitated by the particular rail operation determines the number of traincrews required.

Forty traincrews, including both road and switch crews, can be provided daily by the transportation railway battalion's attached train operating company. Road crews should not work more than a 12-hour shift to allow sufficient time off for them to rest. In emergencies, however, the 12-hour shift can be exceeded for short periods provided the time off between runs is lengthened proportionately. Switch-crew requirements are based on the number of switch engines in use. Two such crews are required per switch engine per day. Both road and switch-crew requirements are calculated by using formulas in which you find values for the unknowns and substitute them in the formulas.

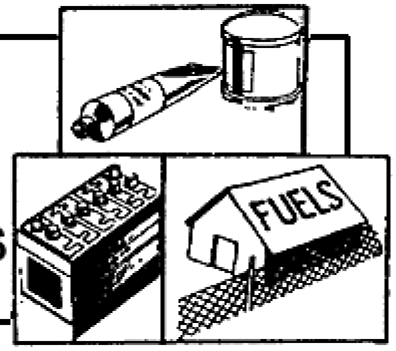
Once you know the number of road and switch crews needed to operate the railroad, you can find the number of railway units needed. The number of railway battalions required determines the number of transportation railway groups needed to supervise the operation. Transportation railway service teams organized under

TOE 55-520 are assigned to assist transportation railway groups or battalions as needed.

The final part of a rail planner's job is to determine the kind and amount of supplies needed to sustain the operation. The next chapter explains how to make this determination.

Chapter 5

SUPPLY REQUIREMENTS



5.1. GENERAL

The number of tons of railway supplies needed to operate a railroad varies with the length of the line and the complexity of the operation. However, railway supply tonnage is generally rather large. Experience has shown that railway operating supplies make up approximately 5 to 15 percent of the tonnage hauled over a railroad. Such supplies are many and varied, but the three principal kinds are fuel, lubricants, and spare parts for the motive power and rolling stock used in the operation. The discussions in this chapter are confined to these three kinds of supplies and the methods of arriving at specific requirements of each.

5.2. FUEL

Steam locomotives use either coal or oil to generate their power, and diesel-electric locomotives use oil to run their diesel engines. Fuel consumption rates for steam locomotives are based on the number of pounds and for diesel-electric locomotives on the number of gallons used. Both are computed by the same method. When more than one type of locomotive is used on a division of rail line, the fuel required for each type must be computed separately.

The fuel required for road engines and switch engines is determined differently. Fuel for road engines is based on the amount they use per train mile, while that for switch engines is based on the amount used per hour. When the monthly requirement for road and switch engines is determined, a reserve factor is added for each type of fuel used: 10 percent for coal and 5 percent for oil. The next three paragraphs explain how to figure fuel requirements for the various kinds of locomotives.

5.3. DIESEL-ELECTRIC LOCOMOTIVES

The average fuel requirements for standard U.S. Army locomotives are listed in table VIII. It shows the oil for diesel-electric locomotives used in road service in gallons per train mile and that for switch engines in gallons per hour of operation. Using the information in the table, the amount of oil required for both road and switch engines can be computed as explained in the following subparagraphs.

a. Road engines. Road-engine fuel is based on the number of trains run daily, the length of the division, and the fuel consumption rate of the locomotive. To find the fuel required for diesel-electric road engines, multiply the number of trains run daily over the division (the train density) by 2 for two-way traffic. Multiply the result by the length of the division to get the number of train miles per day for the division. Remember that when more than one type of road engine is used, the number of train miles for each type must be computed separately. By continuing this procedure for each division and totaling the results, you can find the number of train miles per day for the entire railroad. In table VIII, find the fuel consumption factor for the particular locomotive you intend to use, and multiply the total train miles by that factor. The result is the total gallons of fuel used per day. Then multiply the gallons per day by 30 to find the amount used per month and, finally, add 5 percent to the total to allow for contingencies.

As an example, suppose you are going to operate a two-division railroad using 0-4-4-0, 60-ton locomotives on both divisions. The first division is 96 miles long and has a TD of 8, and the second division is 102 miles long with a TD of 9. Compute the fuel requirements for the locomotives to operate the railroad as follows:

First division:

$$
\begin{array}{rl}
8 & = \text{TD} \\
\underline{\times\ 2} & = \text{two-way travel} \\
16 & = \text{number of trains per day}
\end{array}
$$

$$
\begin{array}{rl}
96 \text{ miles} & = \text{length of division} \\
\underline{\times\ 16} & = \text{number of trains per day} \\
576 & \\
\underline{96} & \\
1{,}536 & = \text{number of train miles per day}
\end{array}
$$

Table VIII. Fuel Requirements for Locomotives

(Data are estimates to be used in Reference Text 603 only)

Type of Locomotive	Estimated rate of fuel consumption	
	Road per train mile	Switching per hour
Standard to broad gage (56 1/2-inch, 60-inch, 63-inch, and 66-inch gage).		
0-6-6-0 diesel-electric, 131-ton, 1,000 horsepower, road switcher	2 gal.	6 gal.
0-6-6-0 diesel-electric, 127-ton, 1,000 horsepower, road switcher	2 gal.	6 gal.
0-6-6-0 diesel-electric, 120-ton, 1,600 horsepower, road switcher	2.5 gal.	11.5 gal.
0-4-4-0 diesel-electric, 120-ton, 1,200 horsepower, road switcher	2.2 gal.	6.4 gal.
0-4-4-0 diesel-electric, 60-ton, 400 horsepower, road switcher	.9 gal.	8.0 gal.
2-8-2 steam, 90-ton, coal-burning, road	115 lb.	750 lb.
2-8-2 steam, 60-ton, oil-burning, road	60 lb.	500 lb.
2-8-0 steam, 82-ton, coal-burning, road	90 lb.	700 lb.
2-8-0 steam, 82-ton, oil-burning, road	55 lb.	450 lb.
0-6-0 steam, 80-ton, coal-burning, switch	---	670 lb.

Second division:

$$\begin{array}{rl} 9 & = \text{TD} \\ \underline{\times\ 2} & = \text{two-way travel} \\ 18 & = \text{number of trains per day} \end{array}$$

$$\begin{array}{rl} 102 \text{ miles} & = \text{length of division} \\ \underline{\times\ 18} & = \text{number of trains per day} \\ 816 & \\ \underline{102} & \\ 1{,}836 & = \text{number of train miles per day} \end{array}$$

$$\begin{array}{rl} 1{,}536 & = \text{number of train miles per day (1st division)} \\ \underline{1{,}836} & = \text{number of train miles per day (2d division)} \\ 3{,}372 & = \text{total train miles per day for both divisions} \end{array}$$

Now, look in table VIII and locate the 0-4-4-0, 60-ton, diesel-electric locomotive. In the column headed "Estimated rate of fuel consumption (road)," you find that it burns 0.9 gallon of oil per train mile. By multiplying the number of train miles per day by the gallons of oil burned per mile, you have the number of gallons used per day.

$$\begin{array}{rl} 3{,}372 & = \text{total train miles per day for both divisions} \\ \underline{\times\ 0.9} & = \text{number of gallons burned per mile} \\ 3{,}034.8 \text{ or } 3{,}035 & = \text{number of gallons burned per day} \end{array}$$

To find the number of gallons burned per month, multiply the number of gallons burned per day by 30.

$$\begin{array}{rl} 3{,}035 & = \text{gallons of oil burned per day} \\ \underline{\times\ \ 30} & = \text{number of days per month} \\ 91{,}050 & = \text{gallons of oil burned per month} \end{array}$$

Finally, you must add 5 percent to the computed oil consumption per month to allow for contingencies.

$$\begin{array}{rcr} 91{,}050 & \qquad & 91{,}050 \\ \underline{\times\ \ .05} & & \underline{+4{,}553} \\ 4{,}552.50 \text{ or } 4{,}553 & & 95{,}603 \end{array}$$

The final figure, 95,603 gallons, is the amount of oil required to operate the road engines on this particular railroad each month.

b. *Switch engines*. Fuel requirements for switch engines are based on the number of these engines required and the hourly consumption rate of each type of locomotive. The average number of hours of operation for switch engines is 20 hours daily; 4 hours are allowed for servicing and maintenance. When estimating the amount of fuel required for switch engines, the first step is to multiply the actual number of switch engines required (not including the 20 percent reserve factor as explained in chapter 3) by 20, the average number of hours of operation. Next, multiply the result by the appropriate fuel consumption factor from table VIII. The result is the fuel consumption rate per day of operation. Multiply this by 30 to find the number of gallons required per month, and add 5 percent to allow for contingencies. Following is an example of computing the fuel requirements for switch engines.

In the example presented in the preceding subparagraph, assume that you have already figured that you need seven switch engines to operate the two-division railroad. Since all engines are the same type, compute the fuel rate as follows:

First, multiply the number of engines required by 20 to find the number of hours of operation per day.

7 x 20 = 140 hours

Second, look at table VIII and find the consumption rate for the 60-ton diesel-electric locomotive; it is 8 gallons per hour. Multiply this consumption factor by the number of hours per day of operation to find the number of gallons of oil required each day.

140 x 8 = 1,120 gallons per day

Next, multiply the gallons per day by 30 to determine the amount required per month.

1,120 x 30 = 33,600 gallons of oil per month

Finally, add 5 percent to allow for contingencies.

33,600 x .05 = 1,680   33,600 +.1,680 = 35,280 gallons

The amount of oil required for the switch engines for these two divisions is 35, 280 gallons per month.

5.4. COAL-BURNING STEAM LOCOMOTIVES

To determine the quantity of coal required for steam locomotives, use the formulas given in subparagraphs a and b below.

a. Road engines.

TD x 2 x LD = TMPD x FCF + 2,000 = STON per day x 30 = STON per month + 10% = total coal required for road engines

where:

TD = train density
2 = two-way travel
LD = length of division
TMPD = train miles per day
FCF = fuel consumption factor
2,000 = pounds per ton
30 = number of days in a month

b. Switch engines.

SE x 20 x FCF = pounds per day x 30 = pounds per month + 2000 = STON per month + 10% = total coal required for switch engines

where:

SE = total switch engines required
20 = average hours per day in operation
FCF = fuel consumption factor
30 = average days per month
10% = reserve factor

5.5. OIL-BURNING STEAM LOCOMOTIVES

The method for determining the quantity of fuel required for oil-burning steam locomotives, both road and switch, is the same as that for coal-burning locomotives. However, only 5 percent is added to allow for contingencies because the losses in heat energy are less when using fuel oil than when using coal.

5.6. LUBRICANTS

The second category of supplies that must be included in railway planning is the lubricants or oil and grease used on motive power and rolling stock. The estimated requirement for these lubricants is 1,000 pounds per month for each train per day operated in either direction over each division. To find the amount required, begin with the first division and multiply the train density by two to allow for two-way traffic. Next, multiply the result by 1,000 to find the pounds required per month for that division. Repeat the process for each division and then total the amount required for all divisions to determine the total pounds of lubricants required per month for the entire railroad.

5.7. SPARE PARTS

The third and final category of supplies is spare parts. Only those parts necessary for the maintenance of motive power and rolling stock are discussed here. An estimated 1.5 short tons of spare parts per month are required for each train per day moving in either direction over each division. Take the train density established for the first division and multiply by 2 for two-way traffic, and then multiply the result by 1.5 to determine the number of short tons of spare parts required for that division each month. Repeat the process for each subsequent division and total the results to determine the number of short tons of spare parts required each month for the entire railroad.

5.8. SUMMARY

Many items of supply are necessary to operate a railroad, but the three principal kinds a military planner must estimate are fuel, lubricants, and spare parts for the motive power and rolling stock used for the operation.

Either coal or oil is used to run steam locomotives, and oil to run diesel-electric locomotives. Fuel consumption rates for steam locomotives are based on the number of pounds used and for diesel-electric locomotives on the number of gallons used. Both are computed by the same method. However, road and switch engine requirements are determined differently. Fuel for road engines is based on the amount used per train mile, and fuel for switch engines on the amount used per hour. A reserve factor of 10 percent for coal and 5 percent for oil is added to the monthly requirement for these engines to allow for contingencies.

The amount of lubricants required is computed separately for each railway division on a monthly basis. These requirements are based on an estimate of 1,000 pounds per month for each train running each way per day over each division.

Spare parts requirements are computed by the same method as for lubricants except that the basis is 1.5 short tons per month for each train per day in each direction.

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TRANS SUBCOURSE 603.................Rail Operations Planning.

(All references are to Reference Text 603.)

LESSON 1

Weight	Exercise
2	1. B, false. (par. 1.1)
2	2. A, true. (par. 1.4a)
2	3. A, true. (par. 1.4)
2	4. B, false. (par. 1.4c)
4	5. A, true. (par. 1.2)
4	6. B, false. (par. 1.3)
4	7. A, true. (par. 1.3)
4	8. B, false. (par. 1.2)
4	9. A, true. (par. 1.3)
4	10. A, true. (par. 2.5)
4	11. A, true. (par. 2.4b)
4	12. B, false. (par. 2.2)
4	13. A, true. (par. 2.5)
4	14. A, true. (par. 2.2)
4	15. B, false. (par. 2.3b)

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work which it pertains.

Supersedes Trans 603, Rail Operations Planning, August 1970.

Weight	Exercise
4	16. B. (par. 2.4)
4	17. A. (par. 2.5)
4	18. E. (par. 2.4a)
3	19. A. (par. 2.4a)
3	20. B. (par. 2.4b)

Computations

126 x 2,000 = 252,000 pounds on drivers
252,000 x .25 = 63,000 pounds starting TE
63,000 x .50 = 31,500 pounds continuous TE

Weight	Exercise
3	21. D. (par. 2.3b)
3	22. D. (par. 2.4b)

Computations

160 x 2,000 = 320,000 pounds on drivers
320,000 x .25 = 80,000 pounds starting TE

Weight	Exercise
3	23. C. (pars. 2.4b, 2.5)

Computations

135 x 2,000 = 270,000 pounds on drivers
270,000 x .25 = 67,500 pounds starting TE
67,500 x .50 = 33,750 pounds continuous TE
135 x 20 = 2,700 pounds
33,750 - 2,700 = 31,050 DBP

Weight	Exercise
3	24. A. (par. 2.4b)
3	25. B. (par. 2.5)

Computations

150 x 20 = 3,000
42,000 - 3,000 = 39,000 pounds DBP

Weight	Exercise
3	26. D. (par. 2.5)

Computations

72,000 x .50 = 36,000 pounds continuous TE
120 x 20 = 2,400 pounds
36,000 - 2,400 = 33,600 pounds of DBP

3 27. A. (par. 2.4)

3 28. B. (par. 2.4a)

The continuous TE is less than the starting TE because the traction motors of a diesel-electric locomotive will become damaged if it continues to exert maximum power for a prolonged time.

3 29. A. (par. 2.3a)

3 30. C. (par. 2.3b)

A diesel-electric locomotive has no trailing wheels; all wheels are drivers.

LESSON 2

Weight	Exercise
5	1. A. (par. 2.12)

Computations

1,000 x .50 = 500 short tons

5 2. C. (par. 2.12)

Computations

850 x .50 = 425 short tons NTL
12,000 ÷ 425 = 28 +, or 29

5 3. C. (par. 2.6)

Weight	Exercise
5	4. C. (par. 2.6, table II)
5	5. A. (par. 2.7)

Computations

20 x 3 = 60

5	6. B. (pars. 2.12, 2.15, 2.16)

Computations

900 x .50 = 450 short tons NTL
NDT = NTL x TD
NDT = 450 x 11
NDT = 4,950 STON (3d division)
EDT = 4,950 STON
The 3d division has the smallest NDT of the three divisions; therefore it is the EDT for the railroad.

5	7. B. (par. 2.9; table III)
5	8. C. (par. 2.13; table IV)

Computations

$$TD = \frac{NT + 1}{2} \times \frac{24 \times S}{LD}$$

$$TD = \frac{7 + 1}{2} \times \frac{24 \times 10}{93}$$

$$TD = \frac{8}{2} \times \frac{240}{93}$$

$$TD = \frac{1,920}{186}$$

$$TD = 10 +, \text{ or } 11$$

NOTE: Only 7 passing tracks should be counted because those at mileposts 39 and 42 are less than 5 miles apart. An average speed of 10 mph should be used because the ruling grade is 1.2. Even though the track is rated exceptionally good, the <u>most</u> restrictive factor governs.

Weight Exercise

5 9. D. (pars. 2.5-2.11; tables II, III)

Computations

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

DBP = continuous tractive effort (CTE) - 20 lb per ton of total locomotive weight

CTE = 50% x starting tractive effort

CTE = 50% x 39,000

CTE = 19,500

Total loco. weight = 65 STON

20% x 65 = 1,300 lb

DBP = 19,500 - 1,300 = 18,200 lb

$$GTL = \frac{18,200 \times .85}{6 + (20 \times 2.3) + (0.8 \times 7.5)}$$

$$GTL = \frac{15,470}{6 + 46 + 6}$$

$$GTL = \frac{15,470}{58}$$

GTL = 266+, or 267

5 10. B. (pars. 2.13b, 2.14; table IV)

Computations

$$TD = \frac{NT + 1}{2} \times \frac{24 \times S}{LD}$$

$$TD = \frac{16 + 1}{2} \times \frac{24 \times 8}{138}$$

$$TD = \frac{17}{2} \times \frac{192}{138}$$

$$TD = \frac{3,264}{276}$$

TD = 11 +, or 12

5 11. A. (pars. 2.12, 2.15)

Computations

860 x .50 = 430 short tons NTL

NDT = NTL x TD

NDT = 430 x 12

NDT = 5, 160

Weight Exercise

5 12. B. (pars. 2.10, 2.11; table II, III)

Computations

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

$$GTL = \frac{33,600 \times .90}{5 + (20 \times 1.5) + (0.8 \times 2.5)}$$

$$GTL = \frac{30,240}{5 + 30 + 2}$$

$$GTL = \frac{30,240}{37}$$

GTL = 817+, or 818 STON

5 13. C. (pars. 2.10, 2.11; tables II, III)

Computations

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

$$GTL = \frac{33,600 \times .90}{6 + (20 \times 1) + (0.8 \times 7.5)}$$

$$GTL = \frac{30,240}{6 + 20 + 6}$$

$$GTL = \frac{30,240}{32}$$

GTL = 945

5 14. D. (pars. 2.10, 2.11; tables II, III)

Computations

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

$$GTL = \frac{35,310 \times .90}{5 + (20 \times 2.9) + (0.8 \times 10)}$$

$$GTL = \frac{31,779}{5 + 58 + 8}$$

GTL = 447+, or 448

448 x 2 = 896 (double-headed locomotives)

Weight Exercise

5 15. A. (pars. 2.10, 2.11; tables II, III)

Computations

$$GTL = \frac{DBP \times W}{RR + GR + CR}$$

$$GTL = \frac{33{,}600 \times .90}{7 + (20 \times 1.1) + (0.8 \times 5)}$$

$$GTL = \frac{30{,}240}{33}$$

GTL = 916+, or 917

5 16. A. (par. 2.12)

Computations

NTL = .50 x GTL
NTL = .50 x 818
NTL = 409 STON

5 17. B. (par. 2.12)

Computations

NTL = .50 x GTL
NTL = .50 x 917
NTL = 458+, or 459 short tons

5 18. D. (pars. 2.15, 2.18f)

Computations

NDT = NTL x TD
.50 x 945 = 472+, or 473 NTL (2d division)
NDT = 473 x TD
NDT = 473 x 10
NDT = 4,730 short tons

Weight	Exercise
5	19. C. (pars. 2.15, 2.18f)

Computations

NDT = NTL x TD
.50 x 896 = 448 NTL (3d division)
NDT = 448 x TD
NDT = 448 x 10
NDT = 4,480 short tons

5	20. A. (par. 2.16)

Computations

NTL (STON)	1st Div	2d Div	3d Div	4th Div
	409	473	448	459

NDT = NTL x TD = 10 for each division

NDT =	4,090	4,730	4,480	4,590

EDT = 4, 090 because it is the most restrictive NDT of the 4 divisions.

LESSON 3

Weight	Exercise
5	1. B. (par. 4.2)
5	2. C. (par. 3.8; table VII)

Computations

Table VII show that 1 switch engine is required per 67 cars dispatched and received per day at port or loading terminals.
2 x 349 = 698
698 + 67 = 10+, or 11 switch engines

5	3. A. (par. 3.4)
5	4. D. (par. 4.5b, c)

Weight	Exercise
5	5. A. (par. 3.4; fig. 3.1)

Computations

2 days at port
2 days over 1st division (1 day forward, 1 day return.)
2 " " 2d " (" " 1 " ")
2 " " 3d " (" " 1 " ")
2 " " 4th " (" " 1 " ")
2 " " 5th " (" " 1 " ")
1 day at railhead
13 days turnaround time

5 6. B. (par. 3.4)

5 7. C. (pars. 4.2, 4.3)

Computations

Number of road crews = $TD \times 2 \times \frac{RT + 3}{12} \times 1.25$

$= 12 \times 2 \times \frac{10 + 3}{12} \times 1.25$

(The value 10 for RT was obtained by dividing the length of the division by the average speed, $96 \div 10 = 9+$, or 10.)

$= 24 \times \frac{13}{12} \times 1.25$

$= \frac{390}{12}$

= 32+, or 33 road crews

5 8. B. (pars. 3.4, 3.5)

Computations

DD = EDT x percent + car capacity 2,795
2,795 x .60 = 1,677 + 20 = 83+, or 84 boxcars
2,795 x .40 = 1,118 + 20 = 55+, or 56 flatcars

Weight	Exercise
5	9. A. (pars. 3.6, 3.7; table VI)

Computations

$$\text{Road engines} = TD \times \frac{RT + TT}{24} \times 2 \times 1.20$$

$$\left(RT = \frac{120}{10} = 12;\ TT = 8\right)$$

$$= 15 \times \frac{12 + 8}{24} \times 2 \times 1.20$$

$$= \frac{720}{24} = 30 \text{ road engines}$$

5 10. B. (par. 3.8; table VII)

Computations

560 x 2 = 1,120
1,120 ÷ 67 = 16+, or 17 switch engines

5 11. A. (pars. 3.4, 3.5)

Computations

56 x 7 = 392; 392 x .10 = 39+, or 40
45 x 7 = 315; 315 x .10 = 31+, or 32
12 x 7 = 84; 84 x .10 = 8+, or 9
392 + 40 = 432 boxcars
315 + 32 = 347 gondolas
84 + 9 = 93 flatcars
872 total requirement

5 12. C. (par. 4.4)

Number of switch crews = SE x 2 x 1.25
(17 - 5 = 12 switch engines)
= 12 x 2 x 1.25
= 30 switch crews

Weight Exercise

5 13. B. (pars. 4.2, 4.3; table IV)

Computations

$$\text{Number of roadcrews} = TD \times 2 \times \frac{RT + 3}{12} \times 1.25$$

$$RT = \frac{99}{6} = 16+, \text{ or } 17$$

$$= 15 \times 2 \times \frac{17 + 3}{12} \times 1.25$$

$$= \frac{750}{12} = 62+, \text{ or } 63 \text{ road crews}$$

5 14. B. (par. 4.4)

Computations

Number of switch crews = SE x 2 x 1.25
= 8 x 2 x 1.25
= 20

5 15. D. (pars. 3.4, 3.5)

Computations

EDT x percent = tons by type + by car capacity = DD
3,800 x .60 = 2, 280 + 20 = 114(DD)
DD x TAT x 10% = number of cars by type
114 x 9 = 1,026
1,026 x .10 = 102+, or 103
103 + 1,026 = 1,129

5 16. C. (pars. 3.4, 3.5)

Computations

3,800 x .30 = 1,140 + 20 = 57
57 x 9 = 513
513 x .10 = 51+, or 52
513 + 52 = 565 gondolas

Weight Exercise

5 17. C. (pars. 3.4, 3.5)

Computations

3,800 x .10 = 380 + 10 = 38
38 x 9 = 342
342 x .10 = 34+, or 35
342 + 35 = 377 flatcars

5 18. C. (par. 3.8)

Computations

114 boxcars
57 gondolas
38 flatcars
209 1DD of all cars
x 2 for 2-way travel
418
418 + 100 = 4+, or 5 switch engines

5 19. B. (par. 4.5)

Computations

45 + 39 +38 + 46 + 47 = 215
215 + 40 = 5+
The number of traincrews (both road and switch) per battalion is 40. The normal assignment is one battalion for each division. The extra 15 crews would be provided by augmentation.

5 20. C. (par. 4.5b)

LESSON 4

Weight Exercise

4 1. A, true. (par. 5.5)

4 2. A, true. (par. 5.3a)

Weight	Exercise
4	3. B, false. (pars. 5.2, 5.3)
4	4. A, true. (par. 5.2)
5	5. C. (par. 5.7)

Computations

TD x 2 x 1.5
15 x 2 x 1.5 = 45 STON

5 6. B. (par. 5.7)

Computations

TD x 2 x 1.5
13 x 2 x 1.5 = 39 STON

5 7. A. (par. 5.7)

Computations

TD x 2 x 1.5
11 x 2 x 1.5 = 33 STON

5 8. D. (par. 5.7)

45 + 39 + 33 = 117 STON

5 9. E. (par. 5.6)

Computations

Lubricants required = TD x 2 x 1,000
15 x 2 x 1,000 = 30,000 lb.

5 10. A. (par. 5.6)

Computations

13 x 2 x 1,000 = 26,000 lb.

Weight	Exercise
5	11. D. (par. 5.6)

Computations

11 x 2 x 1,000 = 22,000 lb.

5 12. B. (par. 5.6)

30,000 + 26,000 + 22,000 = 78,000 lb.

5 13. C. (par. 5.3b)

Computations

Fuel required = SE x average no. hrs. each is operated daily x fuel consumption factor x 30 (no. of days per mo.) + reserve
Switch engines = 5 + 3 + 3 + 5 = 16
16 SE x 20 hrs opn x 8 FCF x 30 days per month = 76,800
76,800 x .05 reserve = 3,840
76,800 + 3,840 = 80,640 gal per mo

5 14. C. (table VII)

5 15. B. (pars. 5.4a, 5.5)

Computation

2,740 x .05 reserve = 137

5 16. D. (par. 5.4a)

5 17. D. (par. 5.3a)

Computations

900 train miles per day
x 2 fuel consumption factor
1,800 gallons per day

Weight	Exercise
5	18. A. (par. 5.6)

Computations

$$\begin{array}{l} 10\ \text{TD} \\ \underline{\times 2}\ \text{(for two-way travel)} \\ 20 \\ \underline{\times 1{,}000} \\ 20{,}000\ \text{lb.} \end{array}$$

5	19. A. (pars. 5.6., 5.7)
5	20. C. (pars. 5.2, 5.5; table VIII)

Coal-burning steam locomotives use more fuel per train than oil-burning steam locomotives; also a 10 percent reserve is allowed for coal and only 5 percent for oil because the loss in heat energy is more when using coal than when using oil.

Table I. Characteristics of United States Army Locomotives

Type of Locomotive	Weight on Drivers (STON)	Starting TE (lb)	Total Weight (STON)	Maximum Curvature Transversible Degrees
Standard to broad gage (56 1/2-in, 60-in, 63-in, and 66-in gage).				
0-6-6-0 diesel-electric, 131-ton, 1,000 horsepower, road switcher.	131	75,700	131	24+
0-6-6-0 diesel-electric, 127-ton, 1,000 horsepower, road switcher.	127	75,700	127	24+
0-4-4-0 diesel-electric, 120-ton, 1,200 horsepower, road switcher.	120	72,000	120	29+
0-4-4-0 diesel-electric, 65-ton, 400 horsepower, road switcher.	65	39,000	65	75
2-8-0 steam, 80-ton, road	70	34,100	146	25

NOTE: The starting TE given in this table may also be used as the continuous tractive effort for steam power. For diesel-electric power, the continuous TE is one-half of the starting TE.

Table II. Average Values of Rolling Resistance (RR)

Track	Pounds per ton of train
Exceptionally good	5
Good to fair	6
Fair to poor	7
Poor	8
Very poor	9

Table III. Effect of Weather Upon Hauling Power of Locomotives

Most adverse temperature in °F.	Loss in hauling power (percent)	Weather factor (percent)
Above +32	0	100
+16 to +32	5	95
0 to +15	10	90
-1 to -10	15	85
-11 to -20	20	80
-21 to -25	25	75
-26 to -30	30	70
-31 to -35	35	65
-36 to -40	40	60
-41 to -45	45	55
-46 to -50	50	50

Table IV. Determining Average Speed Values

Track	Percent of ruling grade	Average speed (mph)	
		Single track	Double track
Exceptionally good	1.0	12	14
Good to fair	1.5 or less	10	12
Fair to poor	2.5 or less	8	10
Poor	3.0 or less	6	8

Table V. Characteristics of U. S. Army Rolling Stock

Type of car	Gage	Capacity tons	Tare weight (empty tons)	Inside dimensions		
				Length	Width	Height
I. Foreign Service						
Box (30-ton)	Narrow	30	13.6	34' 5 1/2"	7' 3/4"	6' 4"
Box (40-ton)	Std to broad	40	18.5	40' 6"	8' 6"	6' 5 3/4"
Flat (30-ton)	Narrow	30	10.9	34' 5 7/8"	7' 2"	
Flat (40-ton)	Std to broad	40	14.5	40' 9"	8' 7 1/4"	
Flat (80-ton)	Std to broad	80	35.3	46' 4"	9' 8"	
Flat, depressed center (70-ton)	Std to broad	70	41.5	50' 7"	9' 8"	
Gondola, high side (30-ton)	Narrow	30	13	34' 5"	6' 10 1/2"	4' 0"
Gondola, high side (40-ton)	Std to broad	40	18	40' 0"	8' 3 3/4"	4' 0"
Gondola, low side (30-ton)	Narrow	30	12.1	34' 6"	6' 10 1/2"	1' 6"
Gondola, low side (40-ton)	Std to broad	40	16	40' 4 1/2"	8' 3 1/4"	1' 6"
Tank, POL (6,000 gal)	Narrow	20	16			
Tank, POL (10,000 gal)	Std to broad	35	19			
II. Domestic Service						
Box (50-ton)	Std	50	23	40' 6"	9' 2"	11' 0"
Flat (50-ton)	Std	50	25.5	43' 3"	10' 6"	
Flat (70-ton)	Std	70	27	49' 11"	10' 3"	
Flat (100-ton)	Std	100	35	54' 0"	10' 6 1/2"	
Gondola, high side (50-ton)	Std	50	25	41' 6"	9' 6"	4' 6"
Gondola, low side (50-ton)	Std	50	23	41' 6"	9' 6"	3' 0"
Tank, POL (10,000 gal)	Std	50	23			

NOTE: Average payload for each type of car except tank cars, is 50 per cent of the rated capacity.

Table VI. Terminal Time Average Values

Type of motive power	Hours
Diesel-electric	3
Steam-powered	8

Table VII. Disposition of Switch Engines

Location	Switch engines required
Port or loading terminals	1 per 67 cars dispatched and received per day
Division terminals	1 per 100 cars passing per day
Railhead or unloading terminals	1 per 67 cars dispatched and received per day

Table VIII. Fuel Requirements for Locomotives

(Data are estimates to be used in Reference Text 603 only)

Type of Locomotive	Estimated rate of fuel consumption	
	Road per train mile	Switching per hour
Standard to broad gage (56 1/2-inch, 60-inch, 63-inch, and 66-inch gage).		
0-6-6-0 diesel-electric, 131-ton, 1,000 horsepower, road switcher	2 gal.	6 gal.
0-6-6-0 diesel-electric, 127-ton, 1,000 horsepower, road switcher	2 gal.	6 gal.
0-6-6-0 diesel-electric, 120-ton, 1,600 horsepower, road switcher	2.5 gal.	11.5 gal.
0-4-4-0 diesel-electric, 120-ton, 1,200 horsepower, road switcher	2.2 gal.	6.4 gal.
0-4-4-0 diesel-electric, 60-ton, 400 horsepower, road switcher	.9 gal.	8.0 gal.
2-8-2 steam, 90-ton, coal-burning, road	115 lb.	750 lb.
2-8-2 steam, 60-ton, oil-burning, road	60 lb.	500 lb.
2-8-0 steam, 82-ton, coal-burning, road	90 lb.	700 lb.
2-8-0 steam, 82-ton, oil-burning, road	55 lb.	450 lb.
0-6-0 steam, 80-ton, coal-burning, switch	---	670 lb.

FORMULAS

Continuous tractive effort	= 50% of starting tractive effort for D-E locomotives. = the same as starting tractive effort for steam locomotives.
Curve resistance	= 0.8 x ruling curve.
End delivery tonnage (EDT)	= NDT of the most restrictive division of the railroad.
Fuel for coal-burning road locomotives	$= \frac{TD \times 2 \times LD \times FCF}{2,000} \times 30 + 10\%$.
Fuel for coal-burning switch locomotives	$= \frac{SE \times 20 \times FCF}{2,000} \times 30$
Fuel for oil-burning road locomotives	$= TD \times 2 \times LD \times FCF \times 30 + 5\%$
Fuel for oil-burning switch locomotives	$= SE \times 20 \times FCF \times 30 + 5\%$
Grade resistance	= 20 x percent of ruling grade.
Gross trailing load (GTL)	$= \frac{DBP \times W}{RR + GR + CR}$
Lubricants	$= TD \times 2 \times 1,000$
Net division tonnage (NDT)	$= NTL \times TD$
Net trainload (NTL)	= 50% of GTL
1 day's dispatch by type of car	$= \frac{\text{EDT x percent of EDT to be hauled in each type car}}{\text{Car capacity}}$
Road engines (RE)	$= TD \times \frac{RT + TT}{24} \times 2 \times 1.2$
Rolling resistance (RR)	= (Refer to table II)
Running time (RT)	$= \frac{\text{Length of division}}{\text{Speed}}$
Spare parts	$= TD \times 2 \times 1.5$
Starting tractive effort	= locomotive weight in STON x 2,000 pounds x 25%.
Switch engines at a division terminal	$= \frac{\text{DD of all cars} \times 2}{100}$
Switch engines (SE) at a port or railhead	$= \frac{\text{DD of all cars} \times 2}{67}$
Total rolling stock required	= DD of each type car x turnaround time + reserve factor (par. 3.5)
Train density (TD)	$= \frac{NT + 1}{2} \times \frac{24 \times S}{LD}$
Weather factor	= (Refer to table III)

Appendix I

REFERENCES

Army Regulations

AR 310-25	Dictionary of United States Army Terms
AR 310-50	Authorized Abbreviations and Brevity Codes

Field Manuals

FM 55-15	Transportation Reference Data
FM 55-20	Army Rail Transport Operations
FM 101-10-1	Organizational, Technical, and Logistical Data

Technical Manuals

TM 55-208	Railway Equipment Characteristics and Data

Appendix II

GLOSSARY

Coupler--device for connecting and disconnecting railway cars and locomotives.

Direct support maintenance--category of maintenance authorized for and performed by designated maintenance activities in direct support of using organizations. This maintenance is limited to the repair of end items or unserviceable assemblies on a return-to-user basis.

Division of military railway--that portion of a railroad--ranging from 90 to 150 miles long--assigned to the supervision of a railway superintendent or to one railway battalion.

Double-track main line--main line having two tracks, one for movement of trains in one direction, and the other for trains in the opposing direction.

Drawbar pull--actual pulling power of a locomotive available for pulling a train; it is the tractive effort less the power to move the locomotive itself.

Gage of track--distance between the two parallel rails. Standard gage, almost universal in the U.S., is 56 1/2 inches.

General support maintenance--category of maintenance authorized for and performed by designated TOE and TD organizations in support of the Army supply system; repair or overhaul of materiel to required maintenance standards in a ready-to-use condition based upon applicable supported Army area supply requirements.

Gross tonnage--weight in tons of an entire train less the locomotive and caboose.

Head end--end of the train closest to the engine; also, end of the yard tracks from which locomotives depart.

Logistical support--provision of supplies and services to combat elements. Major logistical functions are supply, transportation, maintenance, construction, labor, and medical evacuation and hospitalization.

Main track--track extending through yards and between stations upon which trains are operated by timetable, train order, or both, or the use of which is governed by block signals.

Net trainload--actual net tonnage or payload carried by one train.

Passing track--same as siding.

Pusher engine--engine used to assist a train out of a yard or over a grade by pushing from the rear end. If the extra engine is on the head end, it is called a helper.

Rehabilitation of rail line--restoring an existing damaged rail line so that it is operational.

Road engine--locomotive used primarily to pull trains over mainline tracks between division terminals.

Siding--track adjacent or parallel to the main track connected by switches at each end used for meeting or passing trains. The length of the shortest siding on a railway division governs the length of trains operated over the division.

Single-track main line--main line having one track for movement of trains in opposing directions.

Switch crew--crew employed in yard switching service.

Switch engine--locomotive used to move drafts or cuts of cars in yards.

Tractive effort--measure of the potential power of a locomotive expressed in pounds; the horizontal force which a locomotive can exert providing the wheels do not slip.

Train--one or more than one engine, with or without cars, displaying markers.

Train density--number of trains that can be operated safely over a division of railway in each direction during a 24-hour period.

Truck--wheel and axle assembly that supports a car or locomotive at either end and carries the journal boxes.

Yard--system of tracks within defined limits provided for making up trains, storing cars, and other purposes, over which movements not authorized by timetable or train order may be made subject to prescribed signals and rules or special instructions.

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