costs. In the long run, he will profit because of a greatly increased yardage for his season's output.

Methods of Hauling Road Materials.—Those engaged in constructing roads and pavements have long realized what a large item of cost is incurred in hauling materials and some discussion of the methods available is pertinent in this paper. Many factors involved in determining the cost of hauling are variable for work in different localities but for a given piece of work the amount of each of these can usually be selected with reasonable accuracy, and the economy of various methods thus compared.

The cost of hauling varies with the following factors:

1. Length of haul.
2. Rate of travel of the outfit used.
3. Amount of time lost at cars while loading and at road while unloading.
4. Amount of time lost on account of bad roads.
5. Capacity of the outfit per trip.
6. Cost of operation of the outfit.

Length of Haul.—Length of haul for a given piece of work is, of course, the same no matter what method of hauling is used.

Rate of Travel.—The rate of travel varies somewhat between outfits of the same kind and yet there is a value that is reasonably near an average for all outfits of a type. For teams 2½ miles per hour, traction outfits 3 miles per hour, motor trucks 10 miles per hour, and for industrial railway 10 miles per hour may be taken as typical speeds, assuming half the distance is traveled empty and half loaded.

Lost Time.—The amount of time lost at cars depends upon the method of loading the outfit. If hand shoveling is resorted to, the time will be relatively long, but extra units of the outfit may be loaded while the others are on the road. This is advisable for all classes of hauling outfits and is a necessity in traction hauling and with the industrial railway. Bins at the sidings with capacity for a full load for the outfit may be used instead of extra units of equipment and are a necessity when the motor truck is used. For team hauling the loading chute may be employed instead of extra wagons. In any case time lost at the cars is expensive, especially on short hauls, and should be eliminated as far as possible.

Records of loss of time in loading and in unloading are exceedingly diverse, but the following amounts lost per trip are near enough the average to give comparable results: With team hauling, 18 minutes; motor trucks (loaded from bins or hoppers), 6 minutes; traction outfits, 30 minutes; and with the industrial railway, 30 minutes.

Time lost due to the condition of the road cannot be evaluated in a discussion like this because it varies throughout the season, differs with the locality and with the kinds of roads over which the hauling must be done. It is greatest with the traction outfit, is about the same for team and motor truck hauling and is a negligible factor for the industrial railway.

The capacities of these outfits per trip are also exceedingly diverse and perhaps no particular one is typical, but equipment of the following capacities are in common use and will serve as examples: Wagons for team hauling, 2 tons; motor trucks, 5 tons; traction outfits, 15 tons; industrial railway trains, 20 tons.

The cost of operation of each of these outfits will vary with the skill of the superintendent, the character of the operator, the kind of weather encountered, and the nature of the road that is used. Cost of operation should include the following items; interest on investment, depreciation on outfit, maintenance of outfit, fuel, oil and other supplies used and labor cost of operation.

These various items must be evaluated in estimating the cost per hour for operation, and a careful study of the subject has led to the assignment of the following values. If any inequalities exist here it will, of course, change the entire relation, but the method of comparing costs of hauling as outlined is applicable and that is the principal object of this discussion. Cost of operation per hour for teams, $0.50; for motor truck, $2.00; for traction outfit, $3.00; for industrial railway, $4.00.

Knowing the relation that exists between these various factors that enter into cost of hauling, an equation may be written to show the cost per ton which is as follows:

$$C = \frac{rd}{us} + \frac{Tr}{u}$$

where

C = cost per ton for a length of haul $= \frac{d}{2}$.

d = distance in miles traveled per round trip.

u = number of tons hauled per trip.

s = speed of vehicle in miles per hour.

T = time lost loading plus time lost unloading.

r = cost of operation in dollars per hour.

If, in the general expression given above, we insert the values of the various factors for each method of hauling we get the unit cost of hauling by that method for any length of haul $\frac{d}{2}$. These are as follows:

$C = 0.1d + 0.075$, for team hauling.

$C = 0.04d + 0.04$, for motor truck hauling.

$C = 0.066d + 0.10$, for traction hauling.

$C = 0.02d + 0.10$, for industrial railway hauling.

In all of this discussion one factor has of necessity been omitted which is of greater importance than any other, and that is the personality of the superintendent. One man fails to make certain equipment pay out and another succeeds in accomplishing remarkable results with it. Two sets of cost data are obtained, the one showing abnormally high costs, the other showing costs that are exceedingly low. No general discussion can ignore these facts, but they cannot be put into data for use in average cases.

Instruction to Engineers.—States, municipalities and a few construction companies seek to insure that no engineer in their employ will allow the organization of which he is superintendent to fall below the average in efficiency. To that end instructions regarding the use and capacity of various kinds of machinery and as to methods of organization are furnished. Some of these manuals of instruction are excellent treatises on highway construction. Three phases of the use of machinery are usually presented and these cover the normal requirements of such instruction.

The general organization of the work is first outlined. Ordinarily some one machine or operation is the pacemaker for the whole job and when that is true the engineer in charge of construction must build up his whole organization about that machine or operation. The instructions can outline a workable organization but the live engineer will usually be able to improve upon the details.