States can be brought down to 5, perhaps 4, or even 3. I make that forecast with confidence, for several reasons. In the first place, we are just entering upon a new era in road building. Our first objective was hard roads; then it was wide roads; and now it's safe roads. Our road engineers know how to build roads that are almost accident-proof—elevated highways in cities and divided roadways in rural areas. The only problem is one of financing. It is my guess that we can finance 20,000 miles of such highways in the thirty years ahead of us, and a substantial percentage of our travel will be attracted to these facilities. An increasing degree of safety will be engineered even into our secondary roads. In the second place, control of the driver through education and selective enforcement is just getting under way. The children now in primary schools will almost all be subjected to safety training in secondary schools. Our 40,000,000 drivers today for the most part learned to drive by catch-as-catch-can methods. In the years to come, they will be supplanted by drivers who have had proper training and who have been drilled in their responsibilities to a motorized civilization. The reckless will be barred from use of the roads; and, finally, as automobile travel becomes safer and more facile, there will be a constantly increasing use of automotive transportation. In 1908 no one would have dared predict 250,000,000,000 vehicle miles in 1938, but I predict 500,000,000,000 miles of annual travel by 1969. I hope that all of you here will be present at that time to say, "We saw it happen."

HANDLING EARTHWORK EFFICIENTLY

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In discussing this subject, it will be assumed that the gentlemen who are listening to this address represent various phases or fields of engineering activity and that, as a result, it is unlikely that an intensive presentation of a single phase of efficiency as applied to the handling of earthwork will be as acceptable as a more general presentation in which comment is made on a considerable number of the phases of this problem. As a result, some of the phases which are of sufficient importance to warrant lengthy comment will be given less consideration than some of you might, perhaps, wish. It has, however, been my hope that the interest you will have in comments on the relation of matters not so often mentioned to the efficiency with which earthwork may be handled will serve to make up for this deficiency.

May I also remark that this address deals with handling earthwork in the highway field. There are, of course, many

other construction fields in which earth is moved in quantity. In most of these fields it will be found that the comments which follow have about as definite an application as they have in the highway field. Perhaps in some fields they cannot be directly applied. Still the principles of efficiency are pretty general in their application. It follows, quite naturally, that if these are so well understood that there is no confusion in the separation of principles from the details of their application, little difficulty will be encountered in applying them in fields quite remote from the field of highway grading.

SCOPE OF EFFICIENCY

Taken in its broadest sense, the handling of earthwork efficiently implies a great deal more than efficiency in handling a relatively simple construction operation. It involves this, to be sure; but long before construction starts it involves the consideration and the correct solution of a good many problems which, unless they are correctly solved, will adversely affect the over-all efficiency at which this work can be performed. It also involves adequate preparation for such matters as the engineering supervision of construction which should be as wise and as alert as the management of efficient construction must be, as well as some other things that will be brought out during the course of this address.

At this point it is perhaps well to remark that there are a number of phases of efficiency, as applied to handling earthwork, just as there are a good many phases of efficiency as this term is applied in other lines of human activity. The phase usually discussed is the efficiency of performance. This is as important in handling earthwork as it is in any phase of highway construction. But performance in any construction field involves work; so one of the most important phases of efficiency is the elimination of unnecessary and unproductive work. Another phase of efficiency is the reduction of friction. Friction, from whatever cause, either slows down operations or adds to the work of performing them. For this reason, in whatever form it takes, it tends to reduce efficiency. There are, of course, other phases of efficiency; but by mentioning only these it has, perhaps, been made sufficiently clear that efficiency is something more than a matter of good performance.

It has been remarked that if earthwork is to be handled with real efficiency, a start in this direction must be made long before construction begins. The reason for this statement has been somewhat clarified by the comment that the elimination of unnecessary work is an important phase of efficiency. It is only by making an early attack on this problem that this unnecessary work, as well as all unproductive operations, can be eliminated from what at some time in the future will be a construction job. Actually the promotion of efficiency —and this is particularly true of earthwork—should begin

clear back in the reconnaissance stage of the project and should be intensified in the survey stage. Bearing in mind that efficiency is as much a matter of avoiding unnecessary work as it is a matter of doing the necessary work as effectively as possible, the reason for this statement will, I feel sure, be obvious.

LOCATION

Let me emphasize this fact! Efficiency is not a matter of avoiding work but of avoiding unnecessary work. In the various stages of investigation and survey, out of which the final location of a project is developed, there are literally hundreds of occasions when a choice must be made between doing this or that or something else—of whether the line should go here or can more wisely be moved over there—occasions in which a correct decision can be rendered only when this matter of unnecessary work has been included among the various factors considered.

Let me say again that we are here dealing solely with the elimination of unnecessary work. One would not so place a line as to generate rock work if he could secure an equally desirable line without. Nor would he accept a stream crossing that requires 500 feet of bridge when an equally acceptable crossing requiring only 300 feet is as usefully available. Matters of this sort are so obvious that they require no comment. But there are dozens, often hundreds, of occasions when less obvious matters in equal degree involve unnecessary work—the grade line that is carried a little higher than is necessary, the curve that is thrown a little too far into the hill, the line that is so run that an uneconomical item of borrow results. The list of these things is long, and this is not the place to go into details. The objective has been merely to invite attention to the fact that handling earthwork efficiently begins with the selection of an otherwise entirely satisfactory line that reduces unnecessary work to a minimum. There is a great deal of art in the selection of such a line and a great deal of hard work. Most of all, perhaps, much sound thinking is required before a sound result can be had.

A good deal of emphasis has already been placed on good location as a means of avoiding the movement of unnecessary quantities of materials, of materials that are difficult to handle, of unnecessary borrow, and matters of that sort. It is fully appreciated that more often than not the avoidance of unnecessary work is the joint responsibility of the field parties and of the design staff. Lest question should arise on this point, it should be remarked that the order in which these matters are treated in the design of a specific project may vary a good deal from the order in which they are treated in this address. This is not important. The important thing is an appreciation of the fact that efficiency involves a consideration of these matters by those responsible for handling them.

DESIGN OF HAUL

The next step in handling earthwork efficiently falls more definitely on the drafting room. It may be described as the elimination of unnecessary work in handling the materials that must be handled. Handling earthwork always involves some movement of the material handled. If this movement is over a distance of more than a few feet, haul is involved. Engineers, of course, realize that hauling costs money; but the issue here has been greatly confused by two widely different facts. The first of these is that specifications usually provide for some given "free-haul distance." This is a technical term which all engineers understand. Designs are, quite generally, based on the assumption that as no disposition that is made of the diggings within the free-haul limits will affect the price that will have to be paid for the work done, any design that involves only a modest amount of overhaul is an efficient design.

This assumption can be readily defended on the rather substantial ground that, regardless of the actual amount of haul involved within the free-haul limits, contractors will bid about the then-prevailing market price. That this is true cannot be seriously questioned. The reason for it is a mystery. But to base design on this thought seems a rather short-sighted policy, for while it is a readily demonstrable fact that, in bidding, contractors do not differentiate between jobs on which the average haul is relatively short and those on which it is relatively long, studies the speaker has made do show that bid prices reflect the effect of haul when the average haul is consistently short or consistently long. In short, if designs are consistently worked out to eliminate unnecessary haul, prices eventually will reflect this fact. In this connection, and speaking on the basis of rather extended contact with grading work, I am of the opinion that both engineers and contractors —the latter in particular—would ultimately find it much to their advantage if the free-haul limit on highway work was uniformly reduced to 100 feet. This would bring the matter of haul, as a factor in cost, and its importance in the efficiency with which earthwork can be handled, into the open where everyone—engineers and contractors alike—would be forced to evaluate its importance properly.

These comments, while a little outside the normal boundaries of a discussion of efficiency in handling earthwork, do serve somewhat to emphasize the fact that the movement of a given yardage of material—which we may assume is the minimum yardage necessary for the proper construction of a given highway—does not necessarily mean that no unnecessary work is being required. The most common error is a failure so to balance cuts and fills that the amount of haul is kept as low as possible. When the amount of hauling—the gross distance traveled—is increased over what is necessary, it is

evident the performance of unnecessary and quite unprofitable work will be imposed on the contractor who ultimately will handle the grading.

Also, it is not uncommon to find that, within the free-haul limits, the design as finally worked out results in a succession of long hauls and short hauls. Aside from whatever amount of extra haul could be eliminated by more careful design, wide differences in the haul distance, as between successive cuts, are expensive to execute if power shovels or elevating grader outfits are to be used. In general, contractors working with these tools are not in a position to supply enough hauling equipment to keep their digging equipment busy when the haul is long, and conversely cannot keep all of their hauling equipment busy when the distance is short. To enable the contractor to produce efficiently, the designing engineer must, therefore, avoid both unnecessary haul and unusually long haul. This can ordinarily be done without an undue amount of difficulty if the design engineer appreciates the importance of doing it. The attainment of a high grade of efficiency in handling earthwork will require that more attention be given to this matter.

ELIMINATION OF FRICTION

The elimination of friction as a means of promoting efficiency has been mentioned. It is a field of many ramifications, of which only a few can be mentioned here. Friction, as the term is used here, covers conditions that tend to interfere with effective operations without stopping them. Inadequate working space is a form of friction. In a given state the shoulder-to-shoulder width of the roadway usually is a matter of pretty well standardized practice. Still, the fact remains that the width of the working space and its effect on the efficient operation of construction equipment often deserves consideration. The designing engineer should visualize the conditions likely to prevail during construction and, if he does so, will often find occasion seriously to ponder over whether a couple of feet of extra width of embankment can not be had without any substantial increase in cost for the reason that this extra width will facilitate the operation of the equipment likely to be used.

As another source of friction, it is unnecessary more than to touch on specifications which, no matter how meritorious the thought that lies back of them, on occasion tend to retard production. The modern tendency is to get rid of provisions which have this effect unless they serve some clearly useful purpose, and if they do, so to revise them as to preserve the good there is in them but to eliminate their tendency to restrict output unnecessarily. A typical illustration is found in the requirement used in several states that road rollers, while rolling fills, shall operate in low gear. I know of no reason either practical or theoretical for such a specification, and

strongly suspect it of being the result of imagination rather than of reason or test. Efficiency demands that unless a requirement found in the specifications is definitely useful, it be eliminated.

It is hardly necessary to observe that once construction starts, the engineering oversight of it should, as far as possible, be constructive and helpful. The day of the feeling that a high rate of production is in necessary conflict with a high quality of performance has passed. It is quite as possible for good management to take care of quality as it is of quantity. Indeed, it has been the speaker's uniform observation that, normally, the two go together. The vigor, the drive, and the administrative capacity that are required to build an organization that will deliver quantity finds no difficulty in delivering quality. The lack of these attributes in the management is all but certain to affect quality quite as much as it affects quantity. Today's engineering oversight of construction recognizes these fundamentals and, accordingly, seeks ways in which to maintain quality without obstructing the contractor's effort to secure quantity.

SELECTION OF EQUIPMENT

When a project reaches the construction stage, the amount of material to be removed has been established. The amount of work that must be performed in handling it has also been established. These matters were established by the location of the project and the details of the design as finally worked out. The contractor can not alter them. He must, in short, take the project and build it as designed.

In proceeding with the execution of a given design, the contractor's first consideration should be as to the type of outfit best suited to handle the work. Admittedly, this may seem a bit theoretical for if, as will often happen, the contractor has only one outfit, he has no choice in this matter. Or perhaps it would be better to say that he exercised his choice when he entered a bid on this project in preference to others on which he might have bid.

But if he has a considerable amount of equipment and can outfit the job in several different ways, the selection of the type of outfit he will send out becomes a matter of a good deal of importance, for while earthwork is regularly handled by several widely different types of equipment, the conditions under which the work is to be performed affect the efficiency with which these different types of equipment can handle it very differently. As an illustration, draglines are quite efficient when the work involved is that of constructing embankments out of side borrow which lies close to these embankments. On the other hand, draglines are almost never used in removing materials from cuts and loading it onto wagons. Power shovels are the most efficient tool we have for handling

broken rock, but neither the shovel-wagon nor the shovel-truck outfit can compete with either the modern elevating grader outfit or with modern large scrapers in handling well-lying, ordinary, common excavation within haul distances of the length ordinarily encountered in highway construction. Again, as between elevating grader outfits and modern tractor-drawn scrapers, both working in good common excavation, the latter type of equipment has the advantage wherever hauls of moderate length are involved.

All the facts noted above are related to the more general fact that, as handling earthwork involves three separate and distinct operations—first, digging the material; second, moving it to a place where it is to be used, and third, placing it in its new location—the most efficient equipment setup is the one in which these successive operations are handled with the greatest average efficiency.

DRAGLINE

Dragline work offers a good illustration. We may suppose, for the purpose of this illustration, that the dragline, as installed, is worth $25,000, and that it is handling a bucket that will deliver two cubic yards per load handled. Now it is apparent that if the material that is being handled is being moved to final position by this machine, we are using a $25,000 unit to dig, to haul, and to place. It is equally apparent that when the distance the material must be moved is so short that it takes very little longer to swing the load into position than it would take to swing it over a wagon or a truck and drop it there, dragline operation will be efficient for, as a digging tool, the dragline admittedly is efficient. But as the distance the material is moved increases, the desirability of handling it in this way decreases, for more and more of the time of the dragline is then spent in moving the material—hauling it, if you please—and when it is used in such hauling work the result is the use of a $25,000 outfit for hauling when a $1,000 truck, or a couple of them, could do the work better. Therefore, the limit of economical usefulness of this type of equipment is reached when the distance the material must be moved is such that it can be hauled and deposited more economically by some other means.

TRACTOR-DRAWN SCRAPER

Other types of equipment can be analyzed in more or less this same way to show why they are efficient tools within certain limits, but not the best tools to use beyond those limits. Thus if, as another example, the operation of the tractor-drawn scraper is critically examined, it will be observed that it is not a particularly efficient tool on very short hauls. The reason for this is that, while it hauls efficiently and economically and digs well in good ground, so much time is lost in

digging, in turning, and in depositing each load, that its relative efficiency on very short haul work is measurably reduced. It is only reasonable to remark, however, that in the highway field there is so little very short haul work that ordinarily this characteristic of this particular type of equipment is without practical significance.

OVER-ALL OPERATING COST

These comments lead to the general observation that the type of outfit selected to handle an earthwork contract should be the one which can be expected to place the largest yardage of material per dollar of over-all operating cost. Over-all operating cost, as here used, includes the labor cost the operations of digging, hauling, and placing will involve, the direct operaating expense—that is, the cost of fuel, oil, repairs, etc.—and the cost of wear and tear on the equipment. When the job tooling is examined in the light of probable over-all cost of operation and of the probable output, it usually will be quite clear that some one type of equipment is theoretically the best. I say theoretically advisedly, for practical considerations may, and often do, require the readjustment of conclusions in this field which are theoretically correct. In the efficient handling of earthwork, prospective rainfall during the construction period, and its probable effect on the stability of the ground over which the hauling must be done, is a practical consideration which may easily have more influence on the determination of the type of equipment to use than over-all operating cost. Or, perhaps it would be more accurate to say that after examining over-all operating cost, on the assumption that operating conditions will be good, it should be reexamined in the light of uncontrollable factors that may affect it. Thus, haul distance being rather long, one would normally use trucks in hauling from elevating graders or power shovels; but if a good deal of wet weather is likely and a good deal of poor subgrade may be expected, tractor-drawn wagons would come up for consideration, or perhaps even tractor-drawn, crawler type wagons.

In an address of this sort it is not possible to go into great detail on a matter of this sort, no matter how important it may be. Rather the purpose has been to lay a bit of needed emphasis on the fact that just as the location and the design of a project require attention because it is in these stages that the amount of work to be done is determined, so the job tooling must be carefully studied and thoughtfully worked out because the tooling imposes fixed limits on the manner in which the work will be handled and the cost at which it can be performed.

FUNDAMENTAL OPERATIONS

It has already been observed that, fundamentally, handling earthwork involves three successive operations—digging, haul-

ing, and depositing. To these operations others may be, and often are, added. Rock, for instance, must be drilled and blasted before it can be picked up and loaded. When scrapers are in use, rooter plows or some other tool of this kind may have to be used to break up such materials as shale, lightly cemented gravel, or even tough materials such as gumbo and tough clay. At the dump it may be required that the material be spread in layers and rolled. Sometimes it must also be sprinkled and disked. To the three simple operations of digging, hauling, and depositing, it is not uncommon then to find that others have been added; but none of these need to affect the efficiency with which the major operations are handled, so none of them need to be considered at this point. It may be well, however, to remark here that the outfits used in grading work fall into two distinct classes—those in which digging is done by one unit, hauling by an entirely different type of unit, and depositing generally by a third type, and those in which all the work of digging, hauling, and depositing is handled by a single unit or by several of these units. The management problems which are involved differ as widely as these general types of equipment differ.

OUTFIT TYPES

The first type of outfit is all but universally based on a power shovel or an elevating grader as the digging tool, uses tractor-drawn wagons, tractor-drawn, crawler-type wagons, or trucks for hauling, and bulldozers or blades for spreading the material as it is dumped somewhere near its final position. The second type of outfit uses dredges, draglines, bulldozers, and tractor-drawn scrapers. Of these, the tractor-drawn scrapers are definitely the most important and, indeed, are rapidly becoming the most generally used tool in the highway grading field, if they have not already reached this position.

The outstanding difference between outfits of these two types lies in the fact that, where the first type is used, efficiency in the management of production depends on maintaining a correct balance between the output of the digging unit and the amount the hauling units can move. This does not sound like much of a problem, but in practice it has been found to present one that is definitely complex. Indeed, the speaker has almost never seen either a shovel job or an elevating grader job on which there was a really efficient balance between the tooling of these two operations. The lack of balance ordinarily arises from a failure to provide a sufficient number of hauling units.

In the very nature of the case, the attainment of full efficiency in handling any sort of construction work requires a definite recognition of two facts which are very fundamental. The first of these is that equipment should be used to its full capacity. The second of these is that as, in highway construc-

tion, there normally is no opportunity to store material between successive processes, the tooling of all successive processes must be in balance. When the tooling of some one process is inadequate, it follows as a matter of evident necessity that the output of other processes is reduced to the output of the undertooled process. This obviously being the case, the importance of a balanced tooling becomes apparent.

Take a power shovel outfit as an illustration and assume a shovel that, in good common excavation, picks up 1¼ yards at a bite. This shovel, in the hands of a good operator, can dig and place on the wagons no less than 180 dippers full, or 225 yards an hour. Now, the over-all operating cost of such a shovel should be in the neighborhood of $60.00 a day. Working at capacity, this shovel will then dig and load material for less than 3½c per cubic yard. But if, because of an inadequate supply of trucks, this shovel can turn out only 100 dippers full—125 yards—an hour, the cost of digging and loading rises to 6c per cubic yard handled.

On the other hand, if the contractor provides more hauling units than the shovel can load, the result is that hauling costs are increased. Thus, if six tractor-drawn wagons are in use when only five are needed, it is apparent that hauling costs are six-fifths of what they should be.

The importance of a balanced tooling on power shovel and on elevating grader jobs can be no better indicated than it is by these rather simple illustrations.

OUTFIT CAPACITY

One other observation closely related to these would seem to be in order. This is that more attention should be given to having an outfit of the right size—that is, of the right capacity for output. It is literally true that men can move a lot of dirt, given time enough, with teaspoons. I have never seen a job handled in this way; but I have myself, in the Orient, managed a considerable number of jobs on which the only digging tools were picks and shovels and on which the only hauling equipment was baskets carried by human beings. We say, and correctly, that such methods are uneconomical. Our reason is that they do not make proper use of mechanical power. And then we proceed to reason, much less correctly, that the more power we have the better. But—and right here lies the trouble—power means machinery and equipment and these things, in turn, mean investment.

Now, the mere fact of investment is not to be questioned; but an investment in equipment is like any other investment. It pays to make it only when there is reasonable assurance that it can be kept busy. Equipment idle at the equipment depot produces no profit. Indeed, it is likely to show a definite loss, for it will usually depreciate there just about as fast as it will when it is at work on the job. There is a little

difference in the unit cost at which a ¾-yard shovel, a 1¼-yard shovel, and a 2½-yard shovel will dig and load material, all of them being in the hands of good operators and all of them being served by an adequate supply of hauling units. But the crux of the matter is that this difference is not so great that the small machine—if kept at work—will make more money than the large machine will if it is idle a good deal of the time. In short, the outfit or outfits the contractor selects should fit the jobs he usually has—not the big jobs he secures only once in a while. It is much better—much more profitable—to have a small outfit he can keep busy than to have a big outfit the available amount of work will permit him to operate only part of the time.

WORKING CAPITAL

Then, too, there is the matter of working capital. Buying equipment ties up capital, reduces the working funds the contractor needs in handling his operations. A $50,000 outfit will move a great deal more dirt than a $25,000 outfit. But having it ties up 25,000 extra dollars. If the outfit can be kept busy, well and good; but if the amount of work that is available is only sufficient, normally, to keep the $25,000 outfit busy, that extra $25,000 is of much greater value as working capital than it is ever likely to be in the form of machinery which will spend much of its time in the equipment depot.

HARMONIZING DIGGING AND HAULING

But whether the outfit is of the right size or too large or too small, the fact still remains that while it is working, its efficient operation continues to demand that the capacity of the digging unit and the capacity of the hauling units be kept in harmony. This is fundamental in all sorts of mass production in which there is no opportunity for storage between processes. If this is not done, production is limited to what the most undertooled process can handle. This sounds simple enough; but in the highway grading field, either power shovels or elevating graders being in use, it is by no means as simple as it sounds. This difficulty arises from the fact that the haul distance varies widely from day to day, often from hour to hour. You may reason, and quite naturally, that even this should not result in producing a seriously complex problem. It is, or at least so it would seem, an easy matter to determine the speed at which, let us say, a truck-track-type-wagon unit moves. The time required, per load hauled, for such repetitive operations as dumping the load, turning on the dump, turning at the shovel (or at the elevating grader), and taking on the load may be readily determined. As a matter of fact these operations consume such a uniform amount of time that on any job they become what all of us know as a constant. The result is that,

knowing the travel speed and this constant, the round-trip time per load can be worked out very easily and from it the number of units that should be in operation for any haul distance.

Calculations made on this basis would prove quite adequate were it not for one thing. Complete efficiency in handling earthwork must take into account the facts that equipment involves investment and that investments should be kept at work. Accordingly, it is undesirable to lay up any equipment if it can be usefully employed. Another matter of consequence is that good operators cannot be picked up and discharged at will. They will not work where they are handled in this way. For these reasons contractors find it advantageous, if not absolutely necessary, to study the amount of haul a job involves, what the maximum hauls are, what the average hauls are, etc., and on the basis of this information to determine that six tractor-drawn wagons or fifteen 1½-ton trucks or some other specific number of hauling units of some definite type will be sent out to serve the shovel. Thereafter the problem is not, "How many wagons are to be sent out today?", but, "What haul distances can we assign to the various wagons that will keep them busy, and the shovel, too?" On the correctness of the day-to-day answer to this question much of the profit or loss in today's grading operations depends. Nor is the answer a simple one to find. Assume that you are building a fill for which material is being taken from a cut—the ordinary situation on a highway construction job. It is 1,000 feet from the shovel to the balance point in the fill. The shovel can dig three loads a minute. Each truck takes two dipper loads, an average of 2½ cubic yards. There are 15 trucks. Could you take the plans for a highway and work out, day after day, a distribution of the deliveries from these trucks which would keep them all profitably busy and at the same time show the least loss of time at the shovel? It is not a simple matter nor is it one that often is attempted except on the basis of the superintendent's judgment and experience. But it is one that can be done and in the proper doing of which lies a good deal of profit.

JOB MANAGEMENT

In what has so far been said you have no doubt noted that the emphasis has all been on the doing of those things that are required if real efficiency is to be attained. These things are, if you please, the foundation on which efficiency rests. Its final attainment in the accomplishment of the work itself depends on them. It also depends on making full use of the results of this preparatory work in the handling of the details of construction management. Or, to put it a little differently, if the preparation for efficient construction is complete, the job management can, and with responsible oversight will, be made to produce efficiently. Without this preparation, the best job managemen

will secure other than moderately satisfactory results only if conditions are accidentally favorable. But if the preparation for efficiency is complete, success is by no means an accident. It should be at least a near certainty. Still, no matter how well the preparatory work has been done, such matters as the selection of a competent superintendent and competent operators cannot be overlooked. Neither can the matter of having enough men on the work without having too many, of preserving discipline, of requiring those who are employed to work while they are at work, to put in the proper amount of time and honestly to endeavor to accomplish what the plans for efficiency have made it possible for them to accomplish. This is not a day in which good results come from driving men; it is a day in which good results come only from good planning. But it would be quite improper to leave the thought that a good plan insures a good result. No matter how good the plan is, it must still be executed. This requires not much of drive but a great deal of management. Given a good plan and good management of its execution, the objective—full efficiency in the attainment of the desired results, can be predicted with confidence.

SINGLE-UNIT OUTFITS

I shall take only a moment to comment on that type of dirt-moving units by which the three operations of digging, hauling, and depositing are handled by a single unit. As already noted, the tractor-drawn scraper is the most widely used piece of grading equipment of this kind. It is an efficient tool, and I am convinced that its use will increase. There are several reasons for this. One of these is that while it is primarily a hauling unit, and as such involves about the same investment as is involved in a tractor-wagon unit of similar carrying capacity, it is so efficient as a digging unit that it takes less time, in good common excavation, to pick up a load itself than it takes even a fairly large shovel to load a tractor-wagon unit of the same capacity. It distributes its load so well and so evenly that in the hands of a skillful operator the use of a bulldozer is unnecessary, and it is so heavy that when material is put down in small lifts there is at least a much-reduced need for rolling. A fleet of these tractor-drawn scrapers will therefore handle about as much material as the same number of tractor-wagon units and do this without the cost of owning or of operating a shovel, usually without the bulldozer, and on a good deal of work without the roller. The saving in investment and the saving in operating cost the use of these units involves is, therefore, of such consequence as definitely to encourage their use whenever the material to be moved is such that they can handle it.

But, as important as this aspect of their operation is, it is, in my judgment, of less consequence as an incentive for their

use than the ease with which their use can be managed efficiently. A good deal of emphasis has been laid on the fact that really efficient operation can be maintained on jobs on which power shovels and elevating graders are used only as the tooling of successive operations is kept in balance. There is no such problem where these scrapers are used. The single unit handles the successive operations of digging, hauling, and distributing; therefore, there is no operation that can get out of balance. All that is required of the management is, then, to see that the unit is in the hands of a good operator, that it keeps moving at the right speed, and that it works in the right place. There is nothing difficult in any of this.

In closing, let me say again that I have tried to give you a birdseye view of efficiency as applied to handling earthwork rather than to give you an intensive statement of some phase of efficiency with formulae and the rules for their application. I have tried particularly to emphasize two things—that efficiency has many ramifications and that if the aspect of earthwork in which interest usually centers, the construction operations it involves, is to be handled efficiently, a great many problems must be considered and a proper solution of them reached before, and long before, a pound of dirt is moved. Efficiency, truly, is a very broad field. It quite as truly deserves constant consideration in all the various phases of highway work you gentlemen represent.

BEYOND THE TWO-LANE ROAD

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In considering the field of highway development beyond the two-lane road, our first concern is with the extent of that field, that is, what portion of our highway mileage will reach the stage where more than two-lane pavement is warranted.

There is considerable loose thinking by the layman on this subject. The average motorist is apt to be influenced by conditions at times of abnormal traffic. He will make a trip on Labor Day or some summer Sunday when every other motorist has the same idea. Finding some congestion on the particular road he chooses to travel, he decides that a wider pavement is needed. In fact, he goes farther than merely to decide it is *needed;* he assumes it *will be provided* as a matter of course. In Illinois we are not asked, "*Will* Route X be widened?" nearly so often as "*When will* Route X be widened?" And in 95 cases out of 100 the only honest answer is "Never." Traffic congestion of short duration a few times a year does not justify the heavy expenditure for pavement widening.