HIGHWAY RESEARCH BOARD

Special Report 63

In Commemoration of the 40th Annual Meeting

Highway Research Board

National Academy of Sciences—National Research Council

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HIGHWAY RESEARCH BOARD

Officers and Members of the Executive Committee

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NRC. HIGHWAY RESEARCH BOARD

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National Academy of Sciences—
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Foreword

The Highway Research Board at its Annual Meeting in January 1961 celebrated the 40th anniversary of its organization in its opening General Session on January 10 and at a Dinner Meeting on the evening of January 11. The Executive Committee of the Board authorized the publication in this present Anniversary Volume of addresses from these two sessions.

In addition to the addresses published herein, Dr. Detlev W. Bronk, President of the National Academy of Sciences, spoke informally to the General Session of January 10 of the ever-expanding frontiers of science; of the understanding of Nature that man has thereby acquired; of the contributions to the welfare of mankind made possible by science and its applications by engineers and industrialists. The control man has over his environment in choosing desirable humidity, temperature, and light, and man's lengthened span of life resulting from progress in the biological sciences, were also noted in President Bronk's remarks. Bearing more closely on the interests of the Highway Research Board, man's progress in his speed of travel has advanced from the speed at which he could run to speeds greater than the velocity of sound. Dr. Bronk closed his remarks with the prayer that man be given wisdom to deal with knowledge; the wisdom and will to aid those who are not as blessed with an understanding of the value of knowledge and who do not enjoy the more desirable way of life that is provided by such understanding.

The Highway Research Board as it passes its 40th birthday hopes it may in the future have in still greater measure than in the past the will and the ability to contribute to a desirable way of life through better understanding of highways and highway transportation.

W. A. Bugge, Chairman
Highway Research Board

We must make of the Board a forum where voluntarily the men and women in research can come together to compare notes on progress with others in the same profession.

— Thomas H. MacDonald

Research as an end in itself may be desirable, but without correlation and widespread dissemination, it may also be of little account. Even the lessons taught by experience will not spread without assistance. It is the need for correlation, stimulation, authoritative group study, and dissemination of knowledge that makes necessary some such agency as the Highway Research Board.

— Roy W. Crum

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Academy-Council Greeting to the Highway Research Board

DR. AUGUSTUS B. KINZEL, Chairman, Division of Engineering and Industrial Research, National Academy of Sciences—National Research Council

It is both a pleasure and an honor to represent the Academy-Council in bringing you official words of welcome and greeting.

A 40th anniversary is really a momentous occasion, as it marks the arrival at a vantage point from which one can look both forward and backward.

Looking backward for a moment to the Euclidean geometry and Al-Jebr algebra of our early school days, we recall the axiom and algebraic summation that the whole is equal to the sum of its parts. Today, we realize that this is no longer the complete truth. On almost every hand we hear it said that the whole is greater than the sum of its parts, and this is certainly true in many of the complex organizations of the general society in which we live. Unfortunately, in this complexity, we too seldom hear the statement that the parts are sometimes greater than the whole. Yet, right here in the Academy-Council we have situations of which this might be said with some justification. The Highway Research Board is certainly one of those parts that can and does stand on its own feet. It is large and powerful by virtue of its past contributions.

Looking ahead, then, to the future; do you stand still or go forward? If the past is any indication, you will, of course, continue down the highway of progress!

As you go, you will be called upon to serve in the solving of many new and varied problems. Some of them can be stated today. Many of them are not even on the horizon. Nearly all of them will be complex. For example, you may even be asked to build a highway between what may become a new Department for Urban Affairs and a new division in the Department of the Interior. Special transportation will certainly be needed if this new urban department comes into being.

You are going to have all types of problems that cannot be solved by pouring concrete on the streets. However, you have all sorts of people with capacity, and, as you have realized, they are the important parts of your whole. Judging by the past, therefore, I am sure that you will handle future problems effectively and expeditiously. Your future is great.

Welcome!

Greetings!

And congratulations!

A Look Ahead in Highway Transportation

LAWRENCE R. HAFSTAD, Vice President in Charge, General Motors Research Laboratories

Compared to my colleagues in Detroit, I am a relative newcomer to the automotive industry. For this reason I cannot in any sense be regarded as speaking for the industry in these remarks. I am still less of an authority in the field of traffic and highway engineering. Recognizing the experience represented in this audience, it would be presumptuous of me to try to tell you things about your business which you don't already know. My function must be to tell you things about my business of research which in my opinion might possibly be of interest or value to you. In short, in order that I may speak frankly and freely it should be understood that in your field I speak not as an authority, but as what I would like to be considered—a reasonably competent and sophisticated amateur.

We are all concerned about the future. Here my crystal ball is no better than that of anyone else. However, research scientists do work closer to the frontiers of knowledge than most people, and in recent years have shown a pretty good record of assessing what is and what is not achievable. In this area perhaps I might be able to give some comments on possible developments in the fields of propulsion, guidance, safety and handling, and payload delivery of the particular vehicle in which you gentlemen are interested—namely, the automobile. Let us take a look, therefore, at some of what appear to be current trends and see what kind of extrapolation can be made.

AUTOMOTIVE POWER PLANT POSSIBILITIES

The propulsion field continues to be interesting, as requirements and economic conditions change and various power plants are proposed or re-evaluated for possible applications in the automotive field. With all the competition, I am continually amazed at the versatility and adaptability of the conventional Otto cycle gas engine. The exciting thing is that there seems to be no dearth of challengers, but the champion is never quite displaced. Figure 1 shows the ranking of current competition, and a few remarks on each may be in order.

The gas turbine (Fig. 2) has had much publicity in recent years, and there has been an almost tacit assumption that its use in the conventional car was only a matter of time. This comes from the unjustifiable assumption that because the turbine displaced the conventional Otto cycle gas engine in airplanes, it would inevitably do the same in automobiles. One need only be reminded that an airplane engine is almost always operated at designed speed, whereas a car engine is almost never operated at designed speed, to show how different the duty cycles in the two cases really are. Note also the high fuel consumption for the non-regenerative turbine, and think, too, of the hot Bunsen flame emerging from the exhaust. Low specific weight alone cannot possibly compensate for these handicaps.

The regenerative gas turbine (Fig. 3) improves fuel economy and eliminates the hot exhaust blast. In doing so it has lost its specific weight advantage, and it has also lost its claim to simplicity and concomitant low cost. Even if it is assumed that these negatives can be ultimately overcome by ingenious design and volume production, there is an important hurdle that remains. Turbine wheels operate in the region of 25,000 to 30,000 rpm. The spin-up times from idle to full power run in the neighborhood of 5 to 6 seconds. That is, when one steps on the accelerator nothing happens, then 5 or 6 seconds later the power comes on with a rush. Obviously, this would make crossing at a busy intersection a really sporting proposition! Such problems can also be overcome, but any valid claim for simplicity and low cost will long since have evaporated.

The diesel engine (Fig. 4) is so well known that no comment is necessary other than the reminder that its good fuel economy is offset by high weight, cost and size.

The free-piston engine (Fig. 5) has been highly developed in recent years and can now be considered a successful, efficient and dependable power plant. It is really a competitor to the diesel engine, however, with the advantage of burning lower grade fuels. Its high specific weight and high noise (compression ratios of 30 to 40 to 1) eliminate it as a serious competitor to the conventional automobile gasoline engine.

In spite of occasional references to the contrary by non-technical writers, the old-fashioned piston steam engine has long since been eliminated as a contender. Its inherent low efficiency and the requirement either for an enormous water tank or an enormous condenser keep it out of the running. A modern steam turbine might be considered because it is so much better than its piston counterpart. Its weight would appear to be only slightly higher than the diesel or free-piston engines, but again its low efficiency drops it into the class of the non-regenerative gas turbine on fuel economy.

	SPECIFIC WEIGHT #/HP	FUEL CONS #/HP-HR
NON-REGENERATIVE GAS TURBINE	1	1.00
GASOLINE ENGINE	2	.45
REGENERATIVE GAS TURBINE	2	.55
DIESEL	6	.40
FREE PISTON	7	.60
STEAM TURBINE	8	1.00
STIRLING ENGINE	8	.45
DIESEL-ELECTRIC+ELECTRIC MOTORS	18	.45
FUEL CELL+ELECTRIC MOTORS	60	.10

Figure 1. Comparison of vehicle propulsion systems.

In the same class, weightwise, would be the old-fashioned hot air or hot gas Stirling engine. This is an external combustion en-

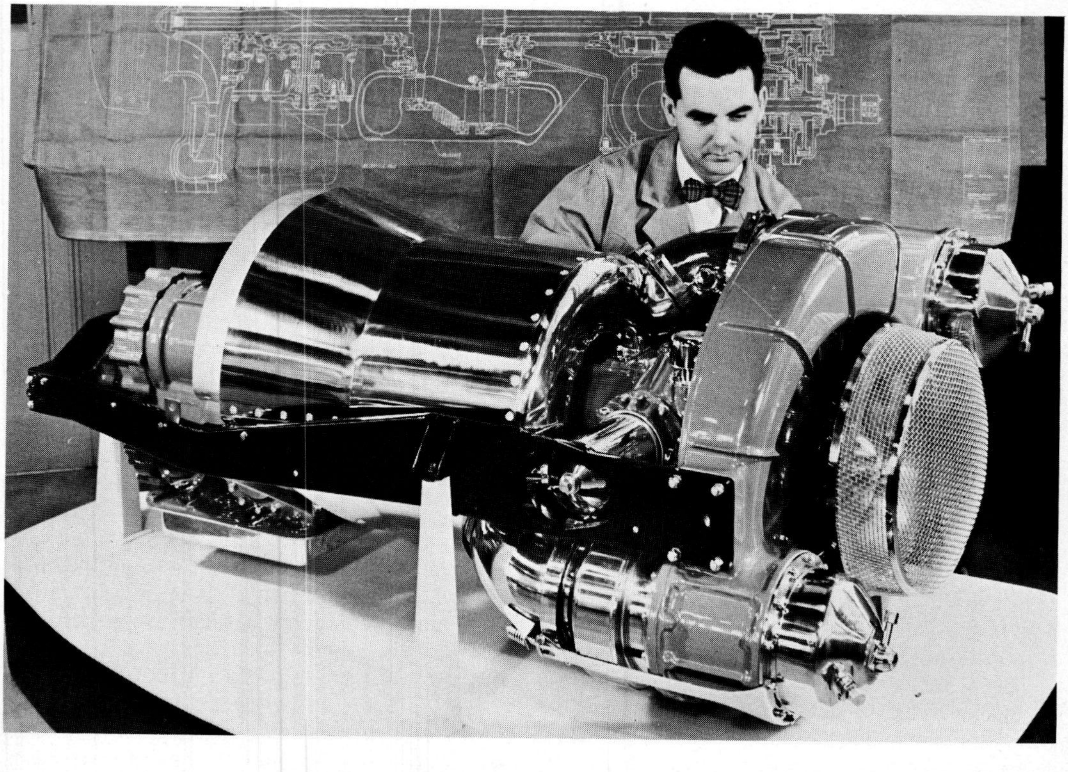

Figure 2. Non-regenerative gas turbine.

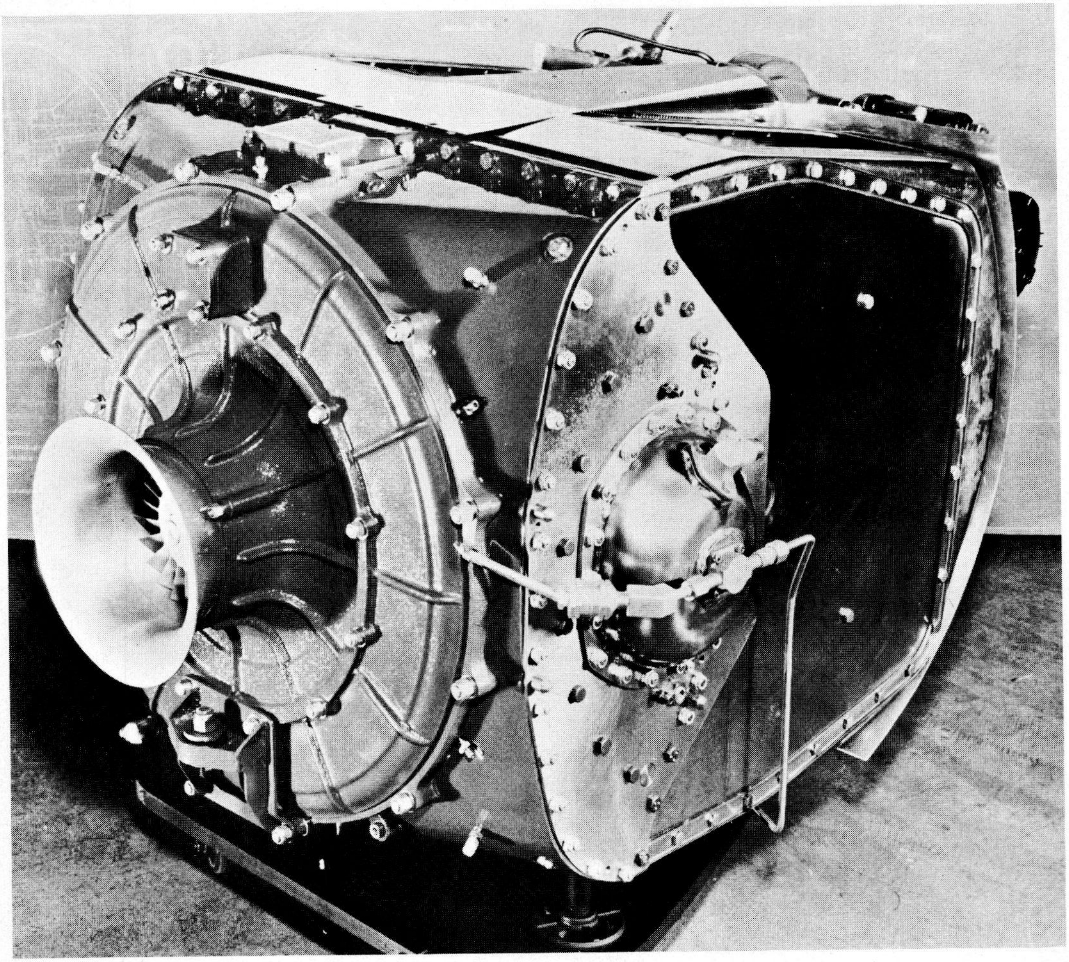

Figure 3. Regenerative gas turbine.

gine with an inherent theoretically high efficiency—even though early versions of this engine had very low efficiencies indeed. This engine (Fig. 6) has recently been brought to a high state of development by work of the Philips Company at Eindhoven, Holland, and the General Motors Research Laboratories (1). Because the Stirling engine, like the steam engine, is essentially a low-temperature device, a low-temperature heat sink is a major advantage. For this reason stationary or marine application would seem to be the natural fields for this engine.

Electric cars are being continually proposed or even announced. In their current versions they are too limited in range and performance by inadequate batteries to be serious competitors to the gasoline automobile. Various combination power plants, such as the diesel-electric can be devised, but these tend to become more complex and still heavier, as the specific weight chart (Fig. 1) shows.

The only really promising "dark horse" in the picture at the present time seems to be the fuel cell as a source of power for an all-electric car. A typical application is shown in Figure 7. This device is essentially a large-capacity primary battery. Being entirely chemical in operation, it avoids completely the Carnot cycle limitations on efficiency (2). Thus, efficiencies of 80 or 90 percent are entirely conceivable. This accounts for the low value given for specific fuel consumption. However, as the weight figure shows, the present versions are much too bulky and heavy, and at

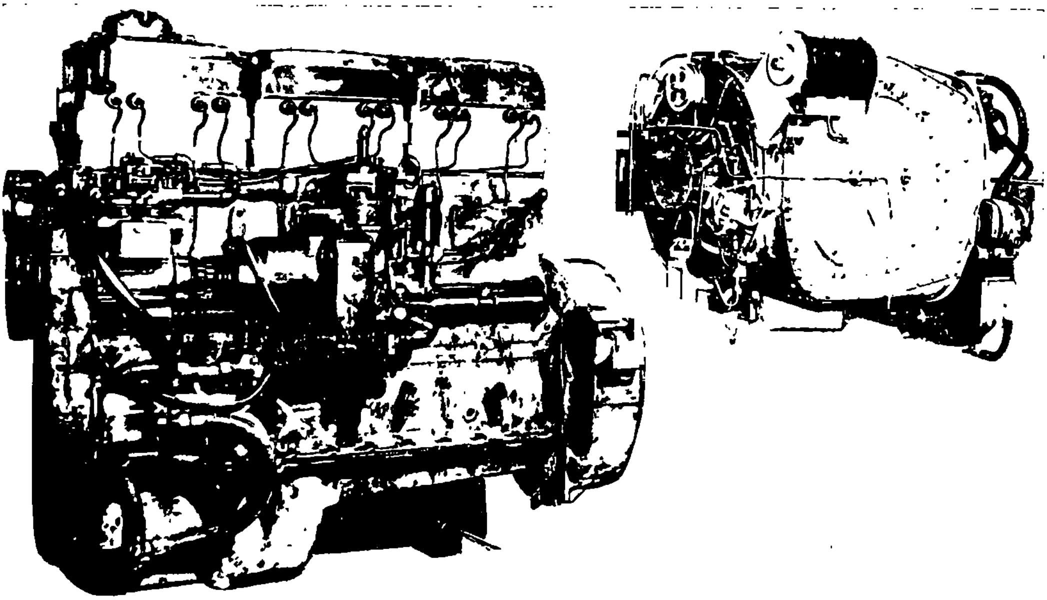

Figure 4. Engine size comparison of diesel (left) and regenerative turbine (right).

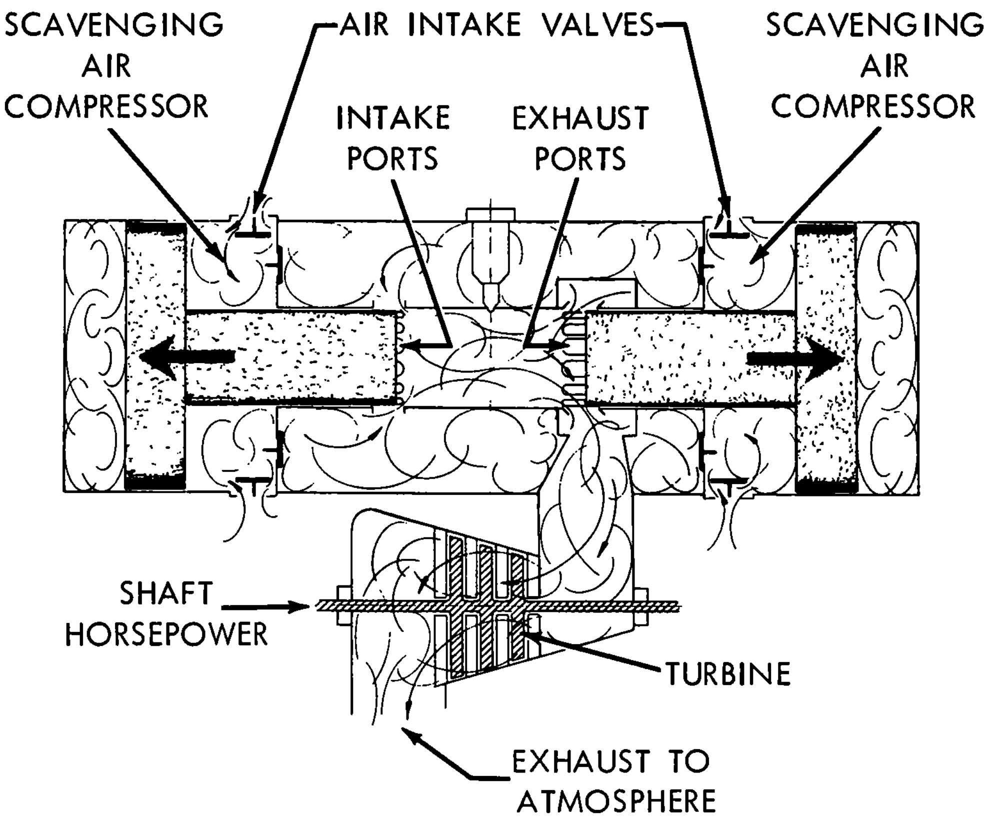

Figure 5. Schematic of free-piston engine.

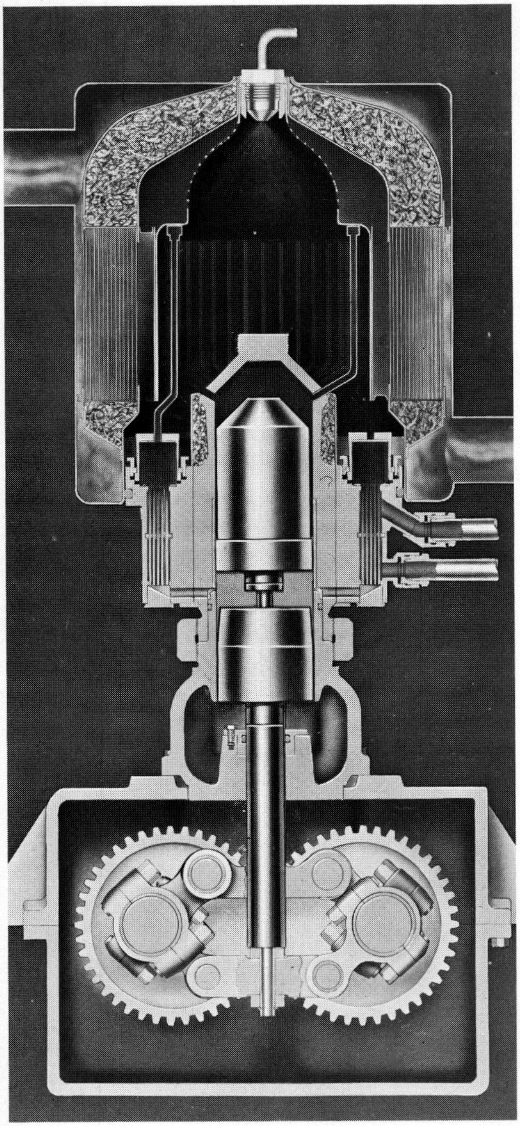

Figure 6. Stirling engine.

the moment also too expensive, for automobile use. The fuel cell has another potential advantage, however, which may prove decisive in certain situations. In some of its many versions the only gaseous end products of the chemical reactions are water or carbon dioxide. The significance lies in the fact that neither of these would be considered to be an atmospheric pollutant.

In summary, then, no significant change is foreseen in power plants in conventional cars in the next decade or two. The one big unknown is the smog situation. If and when a compact high-efficiency fuel cell is developed, its potentially smog-free characteristic may enable it to overcome what would otherwise be an insurmountable cost disadvantage.

THE GUIDANCE PROBLEM

Let us turn now to the guidance problem. Here again the field is exciting, for there are even more variations than in the power plant area. With the rapid advances in the servo-mechanism field, there is no limit to the sophistication which can be introduced into the ride and control field. It would be entirely possible, for example, to put a gyro-controlled stable platform in the car body and thus make its motions independent of the motion of the wheels to any degree that might be desired. On the practical level, however, it must be concluded that manual car control devices have evolved to the point of diminishing returns so far as improvements are concerned. I am reminded of the story of the highly skilled aerodynamicist who thought surely he could make a great improvement in the lumbering Dutch windmills. After much calculation he was forced to conclude that by "cut and try" over the centuries the Dutch had really arrived at a theoretically correct aerodynamic design. The same might be said of manual car controls. Automatic controls will be discussed later.

It might be permitted to interject here some comments on the ground effect vehicle or "air car" (Fig. 8), which has had considerable publicity lately. With modern road materials and modern tires it is the very high "cornering" force available in the conventional car which makes it such a precision transportation instrument. Think of the innumerable times each of us, in complete confidence, passes within 3 or 4 feet of sudden death going in the opposite direction. This is possible only because of the high control forces available. In the air car such control forces are essentially zero. Without adequate control forces such air cars cannot become an essential part of a complex transportation system and must be looked upon as special purpose devices.

Another facet of the guidance problem is the area of driver aids, in which modern technology has much to contribute. Progress seems unduly slow, however, mainly because this is a development area which

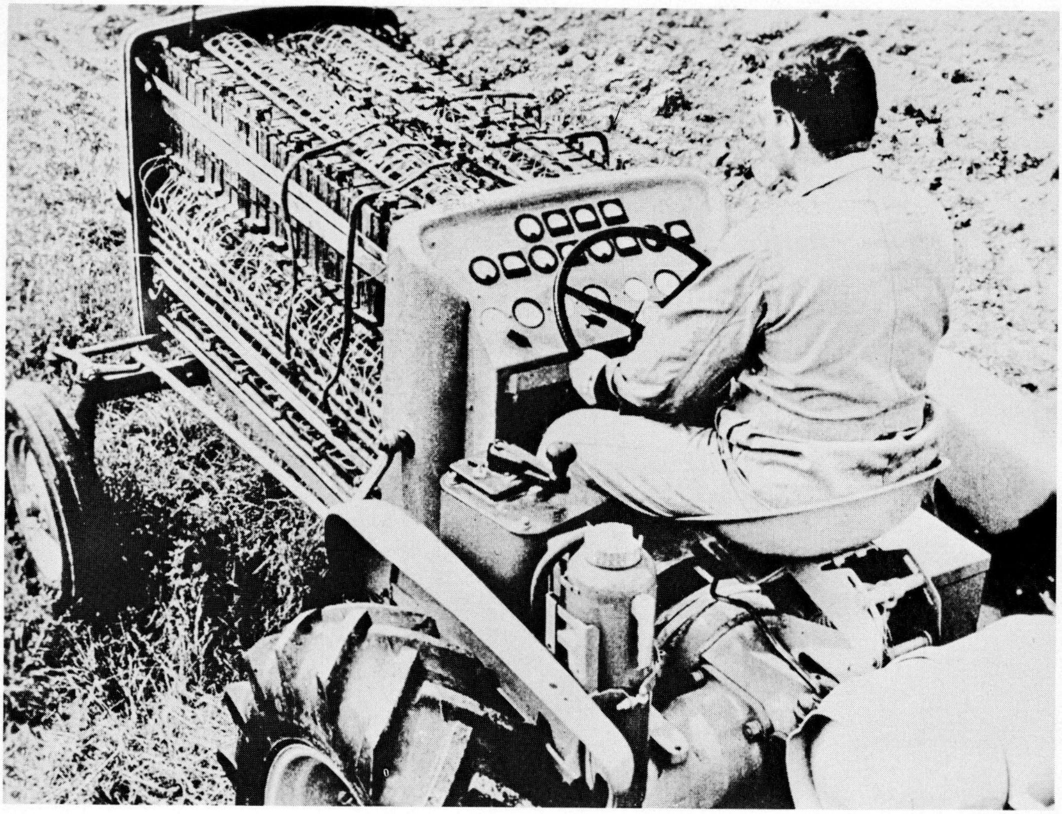

Figure 7. Allis-Chalmers fuel cell tractor.

falls between opposing viewpoints. The car manufacturer sees little point in developing gadgets that have no value to the driver unless complementary road and roadside gear is provided. In contrast, the highway engineer sees no point in providing his part of the gear until a significant number of cars is suitably equipped with the necessary special components. Communication between the roadside and the driver is still

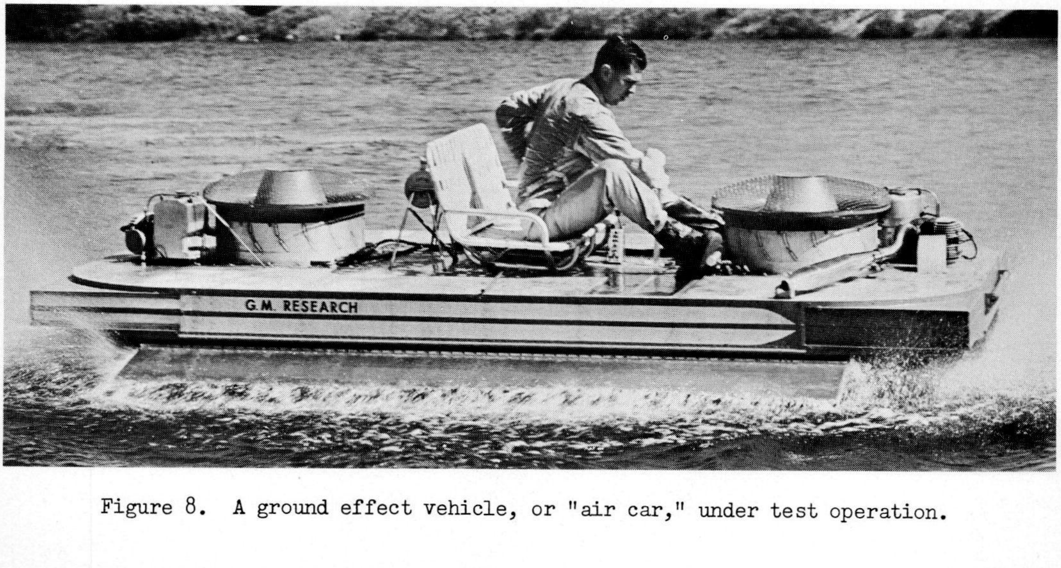

Figure 8. A ground effect vehicle, or "air car," under test operation.

Figure 9. Separation of pedestrian and vehicular traffic in General Motors Futurama display of 1939.

inadequate. This area should be emphasized for urgent attention, but is beyond the scope of the present discussion.

PROBLEMS OF SAFETY AND PAYLOAD

The areas of safety and payload are where the real problems lie and where much research and development needs to be done. One can safely predict a significant upward trend for research in the highway field for the good and sufficient reason that only now is this field beginning to learn how large payoffs in research really can be. Research has paid spectacular dividends in many other fields. Why should it not pay off in this one? As I read it, HRB Special Report 55, on "Highway Research in the United States" (3), claims $17.8 million for research in 1958. The text, however, clearly disclaims much of this as really being research at all. I am inclined to agree, for most of the projects seem to be what would be called product improvement. And although product improvement is valuable, it is really not research, which has been defined as follows:

> "Research is not constructing and manipulation; it is not observing and accumulating data; it is not investigating and experimenting; it is not getting the facts—although each of these activities may play an indispensable part in it. Research is the effort of the mind to comprehend relationships which no one has previously known."

Under this definition, few, if any, of the line items in the tables given in Special Report 55 qualify as real research. Somehow in this $10 billion industry a means must be found to divert a small percentage of the funds to research of the kind which will give an accepted scientific base from which these problems can be attacked.

Nonetheless, we all know that many earnest efforts are being made to find solutions and much excellent work has been done. I am impressed by reports of the work of Miller McClintock and his associates (4) in the 1920's and early 1930's. Many of his analyses and conclusions are valid even to this day. The nature of our current troubles has been clearly brought out in the recent Woods Hole Conference on Transportation Research. One sentence from the report (6) on this conference summarizes the situation, as follows: "...the study of transportation is conducted haphazardly, on a relatively small scale, and rarely in terms of over-all problems of mobility."

It is this over-all approach which has been lacking in the work to date. Work on components, work on bits and pieces of the over-all problem, however diligent and dedicated, will be largely wasted if the bits and pieces fail to fit into a logical whole. To formulate this logical whole it is necessary to develop what I would like to call a philosophy for transportation, with an agreed theoretical basis. This has been developed in recent decades for the communications industry; why should not something similar be done for the transportation industry?

From my own reading I had independently concluded that a greater use of the over-all or systems approach to traffic and transportation problems is urgently needed. It is gratifying, therefore, to find that in the much more carefully considered and authoritative report previously cited the same conclusion is reached. There just must be pay dirt here, and it would appear that an effective way to go after it would be to establish operations research activities in Federal and all State highway offices for the express purpose of interacting with independent university investigators doing similar work in the academic traffic study centers now becoming popular.

An agreed theoretical foundation for transportation and mobility problems should go a long way to reducing the emotional content of much of the current writing on this subject. This in itself would be no small pay-off for those of us waging a losing war with the piles of paper on our desks. Let me try to give some examples from my own experience.

We in Detroit are continually being ap-

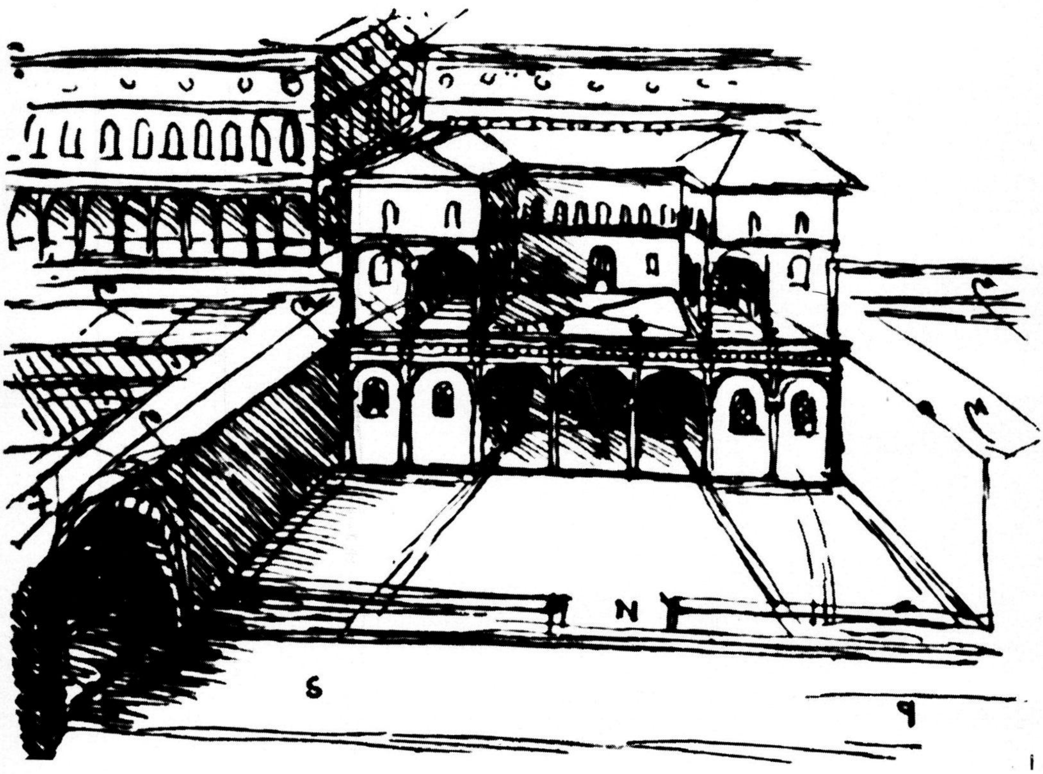

Figure 10. Leonardo da Vinci sketch of ideal city with two-level highways.

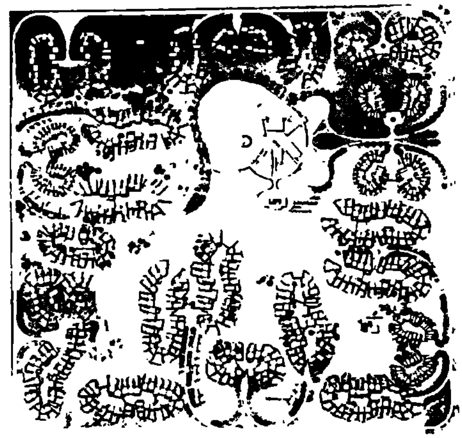

Figure 11. Typical layouts of a suburban development module.

proached by inventors and promoters of transportation devices and systems. Rarely are these accompanied by studies or appraisals of the traffic conditions they are intended to serve. Monorails are the current fad, with high vehicular speeds as the principal advantage claimed. The monorail seems to be a bona-fide example of a solution in search of a problem!

Monorails no doubt will find their proper place in our complex and enormous transportation system. How is this proper place determined? First it should be possible to analyze the basic nature of the over-all problems for which solutions are sought. The various kinds of boundary conditions which may be involved must be determined and specified carefully. It is here that the operations research approach should pay dividends. We must be prepared to deal with the over-all mobility and transportation problem in urban, suburban, and interurban cases. It is axiomatic and elementary that it will be necessary to deal with high-population-density and low-population-density areas, and transportation between them. It should be possible to set up the quite different technical and economic criteria for practical transportation systems for each of the three transitions between population density areas—high-high, high-low, and low-low. This should be simple and elementary, but is ignored in much contemporary writing. In one presumably serious book I read recently for background for this talk, the embarrassing economics and complexities of the foregoing problem were neatly solved by arguments to the effect that people really ought not to want to live in low-population-density areas!

With a systems approach in mind, let us look successively at the areas with which highway-oriented people are normally concerned—namely, urban, suburban, and interurban traffic and transportation.

Take cities first. An operations research man (or a transportation philosopher) would no doubt sit back and ask himself why they are the way they are. Most things about cities "just grew" and most of their new construction or reconstruction proceeds on the basis of pure inertia. There are zoning commissions with the thankless job of adjudicating arguments between various pressure groups. There are innumerable study commissions for individual projects. There are even city planners. In spite of them all, however, bigger buildings get built with inadequate space for transport or parking. Most of these problems are frankly political, so the technical man can only stand aside and assume that when the problems really become bad enough someone in authority will do something about them.

In the meantime, however, there are interesting questions to be raised. In a modern society what are the functions which are uniquely served by the "core" of a large city? What kinds of people are essential to these functions and where are they likely to live? What kinds of facilities are essential and what degrees and kinds of mobility for personnel will be required? What determined the length of the conventional city block in the first place, and why does this particular module continue to be used? What degree of congestion must be tolerated in our two-dimensional pattern before the freely available third dimension will actually begin to be used?

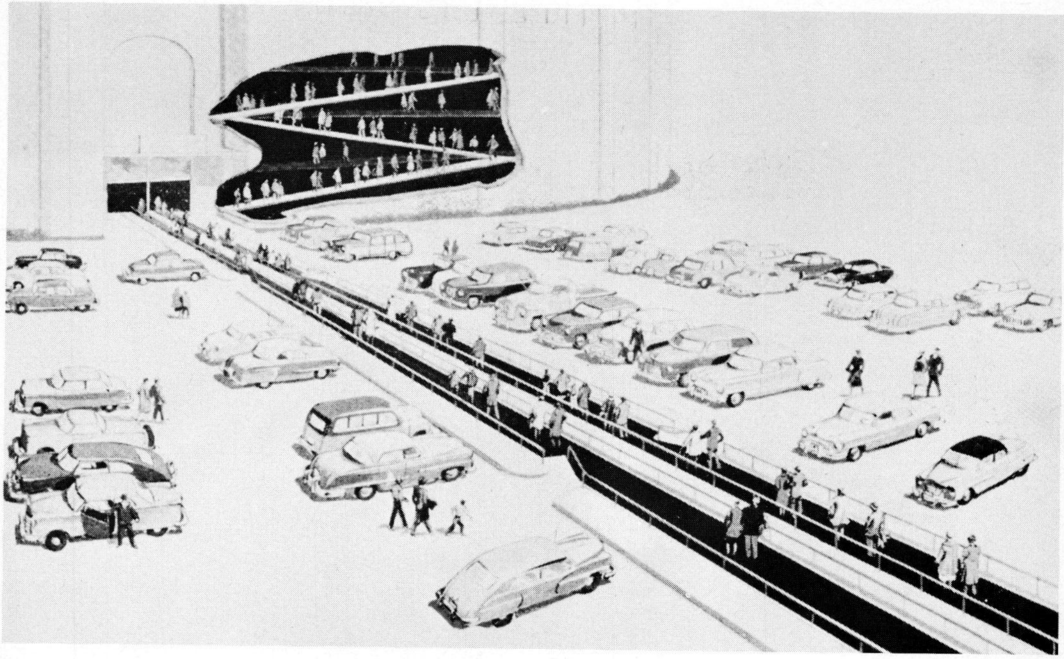

Figure 12. Goodyear passenger conveyors.

In urban areas congestion and safety, especially for pedestrians, seem to be the paramount problems. Why cannot the obvious solution of separating pedestrian and vehicular traffic be adopted, thus solving the pedestrian problem and helping to alleviate congestion? This possible solution was dramatized as long ago as the General Motors Futurama of 1939 (Fig. 9). The suggestion is really much older, having been made by no less an authority than Leonardo da Vinci in the 15th century. Figure 10 shows his concept, which is explained in his notebooks as follows:

"And know that if anyone wishes to go through the whole place by the high-level roads, he will be able to use them for

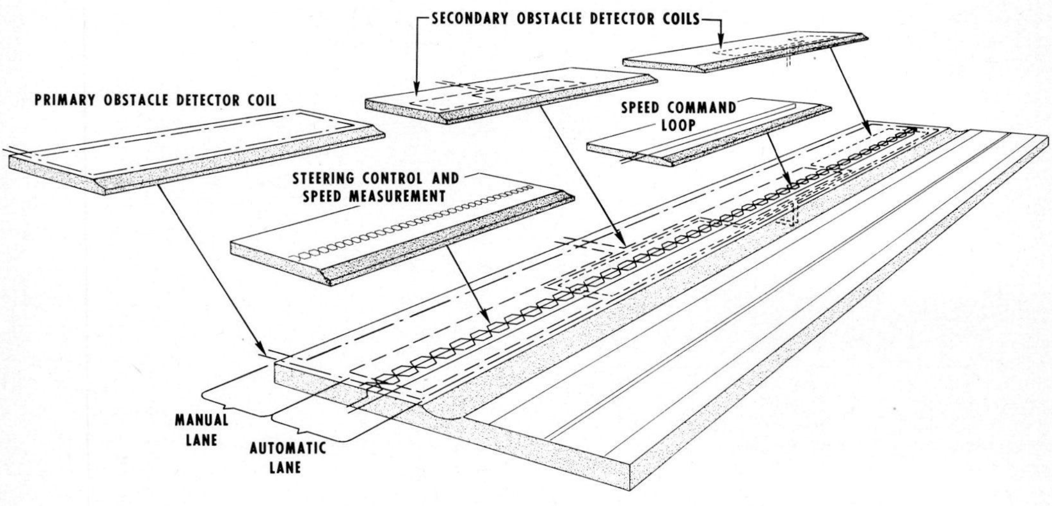

Figure 13. Block wiring schematic of one electronic vehicle control system.

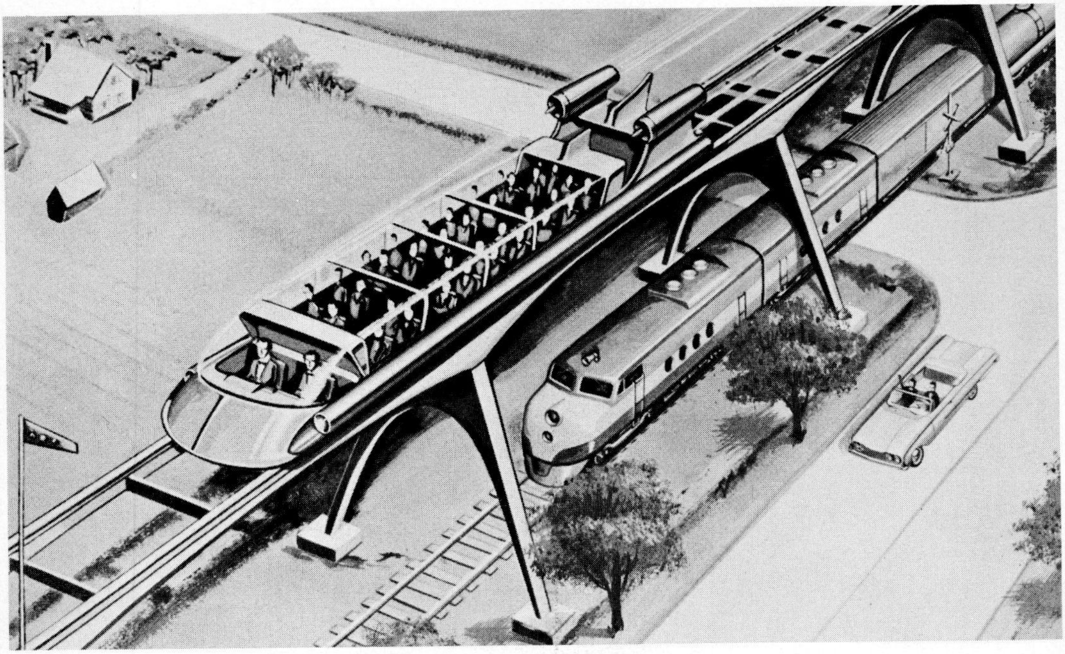

Figure 14. Artist's concept of the "Levacar," proposed by Ford Motor Co.

this purpose, and so also if anyone wishes to go by the low-level roads.
"The high-level roads are not to be used by waggons or vehicles such as these but are solely for the convenience of the gentlefolk. All carts and loads for the service and convenience of the common people should be confined to the low-level roads." (5).

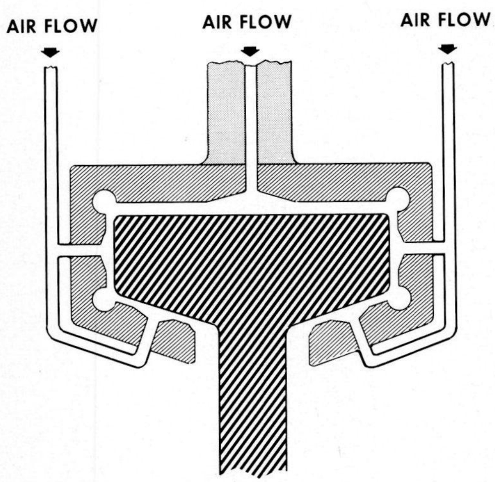

Figure 15. Possible assembly of "Levapads" around a rail.

In urban areas the problems are more political and less technical than in either the suburban or interurban areas. However, an operations research approach would indicate the kinds of activities which would yield the greatest dividends. First, it would be prudent (as in all complex situations) to have the ultimate objective precisely defined and clearly in mind. From my general reading I find this to be far from true, and my impressions are confirmed by this quotation from the Woods Hole Conference report:

"Transportation efficiency in one or another aspect is said to be 'poor' only because of a belief, too often intuitive, that it can be improved--not because either its performance or efficiency can be measured by any accepted rational standard." (6).

A technical man finds it most difficult to attack a problem so vaguely formulated. What is it that is really sought? What is par for the course? What is the theoretical upper limit of achievements under the particular set of boundary conditions, and how close is current achievement to that limit? These are the kinds of questions an operations research or systems approach could attack and begin to answer. Oversimplifying, there seems to be concern with two problems—safety and payload. Each of these is a function of many variables, some technical, some political. If these two functions are imagined as plotted against speed, the engineering compromise which must be made becomes clear, for payload increases with speed but safety decreases with speed.

Because each of the functions contains many variables, including cost, it becomes necessary to explore families of these curves by allocating fixed increments of cost to each of the variables and noting the gain that is made. This approach might help to bring to an end the present stalemate in which lay writers continually call attention to residual technical problems to avoid facing major political issues. For example, cars obviously can be made, at a price, still more drunk-proof and idiot-proof and crash-proof. How would the price of doing this compare with the cost of not licensing drunks and idiots? This would be the operations research approach to the problem.

Of course, I am aware of the arguments that, with personal cars a necessity for transportation to and from work, even the habitual traffic violator cannot be deprived of his license to drive. But one cannot help but wonder why it has not occurred to someone in authority to license the arrogant habitual traffic violator to drive only, say, a 5- or 10-horsepower Go-Kart. Airplane pilots have graded licenses; why shouldn't auto drivers?

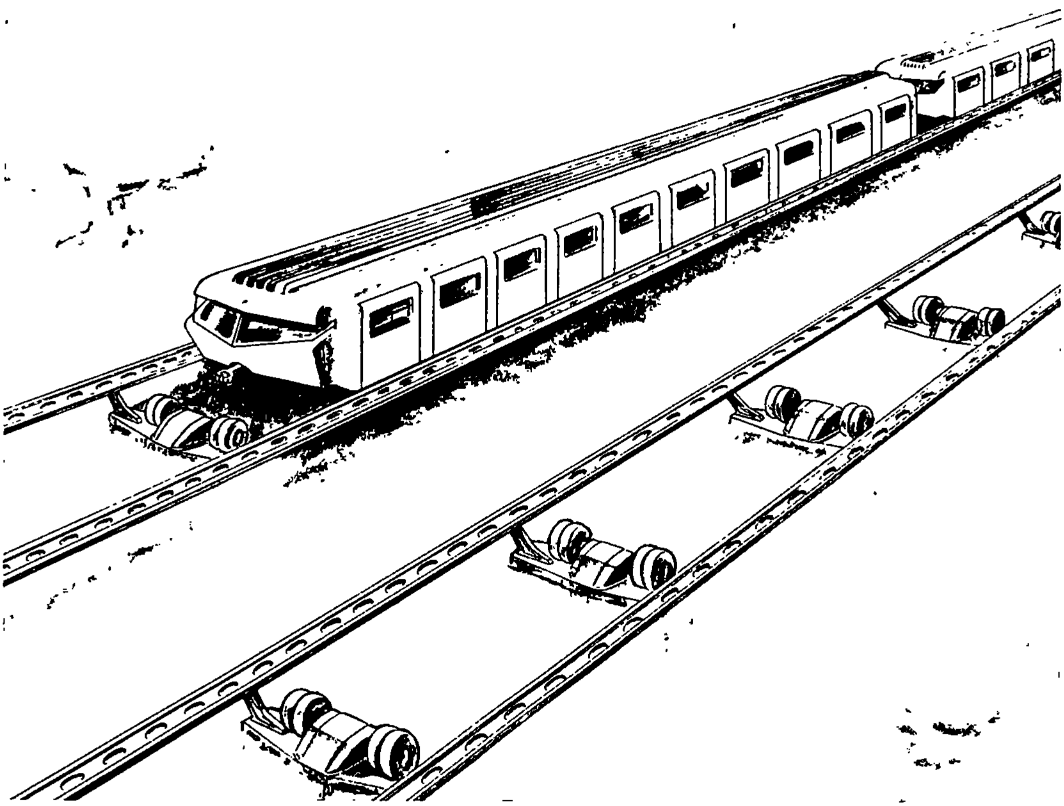

Figure 16. Artist's concept of Westinghouse high-speed transportation proposal.

With respect to the residual technical variables previously mentioned, in urban areas one can foresee much work that will be done in improving electronic traffic control, and an increased use of sensors and computers to direct traffic and to detect and bypass bottlenecks. The Dusseldorf traffic pacer technique, which controls traffic flow so as to reduce or eliminate stops at red lights, or some equivalent, should come into much increased use as traffic densities increase. By and large, however, in urban areas the important parameters in the equation are the political ones, and dramatic advances—that is, gains beyond percentage improvements due to technical contributions—seem somewhat unlikely.

Turning to the case of suburban areas, the problem of safety is still paramount. As in the case for urban areas, the obvious maximum payoff would come from the separation of pedestrian and vehicular traffic. In contrast to urban areas with their crystallized vested interests, the opportunities for moving in this direction in new suburban suburbs to be developed progressively by the addition of successive self-contained and essentially self-sufficient "modules", each with its own shopping, recreational and educational facilities accessible by foot-paths as well as by car. This would seem to be an entirely natural modern extension of the da Vinci suggestion for separation of vehicular and pedestrian traffic.

The optimum size for such a module has yet to be determined, and would represent another opportunity for the systems approach. Current estimates, however, indicate that a module of the order of a half-section should be adequate. Figure 11 shows typical layouts of such suburban development modules (7). A trend in this direction would have a revolutionary impact on both the safety and transportation problems and the future development of city planning.

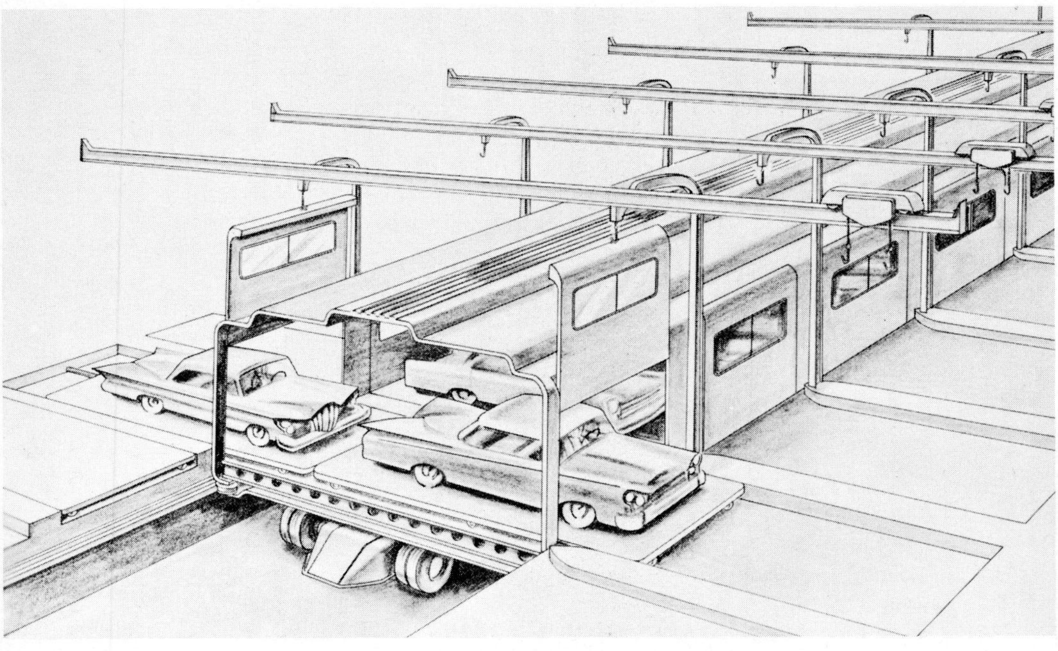

Figure 17. Method of loading and unloading vehicles at terminus.

developments should be numerous. This problem is neither technically difficult nor prohibitively expensive, as preliminary studies by many architectural groups both in the United States and abroad have already shown. The approach might be for

The final case for consideration is that of interurban traffic. Here, because of the great distances involved, high speed is a paramount requirement and with high speed comes an increased hazard. This hazard problem will be returned to later. Compared to the urban problem the interurban problem is relatively more technical and less political. As might be expected under these conditions, there is a really interesting assortment of new developments.

It is characteristic of traffic composed of independently controlled units that as volume increases the average speed decreases. One might say that present traffic systems have a large negative volume coefficient. For any significant increase in speed, therefore, it becomes essential that some form of controlling a multiplicity of units be established. In principle this can be done in a variety of ways—placing the independent units on a moving belt, hitching the independent units to a moving cable, or combining the independent units into convoys or trains.

Ideally, one would like to be able to start from either an urban or a suburban home, drive unhurriedly to the nearest expressway entrance and there be placed (car and all) into position on a moving belt going at some really high speed, such as 200 mph. On arrival at the proper expressway terminal the process would be reversed, the car removed from the belt, and the driver left free to proceed to his destination with his own car and as much personal baggage as he chooses to carry. This old idea is obviously impractical; but it is theoretically correct—and this is important—in that it meets all the desires of the driver. One can now proceed to evaluate other proposals by comparing them with this idealized solution.

Of course belt systems are actually in

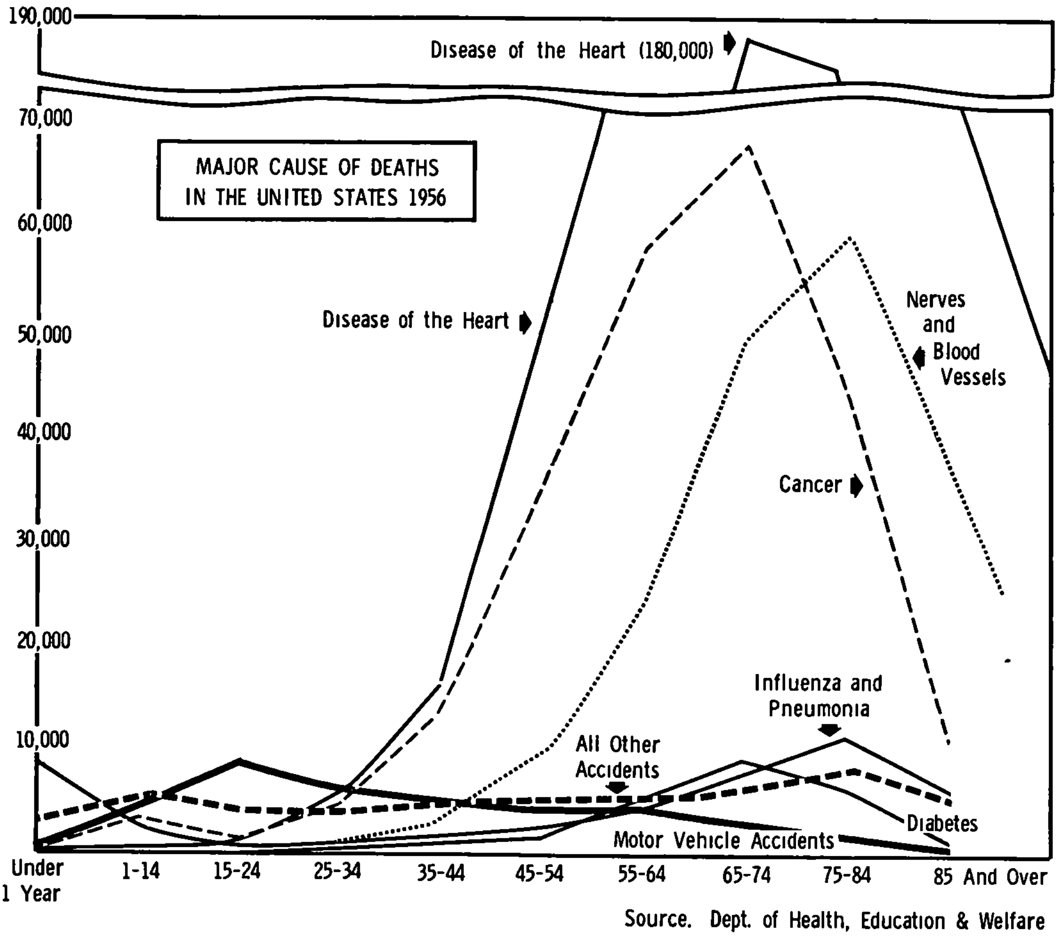

Figure 18. Major cause of deaths in the United States, 1960. (Source: U.S. Dept. of Health, Education and Welfare.)

use for material hauling, but so far only for short-haul pedestrian traffic. A recent Goodyear proposal is shown in Figure 12 (8). In their present form such belt systems do not meet the requirement for interurban traffic where high speed is essential.

The various systems for automatic electronic control of cars are in effect versions of this moving belt or moving cable approach. The car to be controlled is "trapped" in a controlled radiation field, which is then moved along the road at the chosen rate of speed. These systems are definitely technically feasible, as has been demonstrated by recent work of the Radio Corporation of America, as well as General Motors. Interest in these systems stems from the fact that they could conceivably meet the requirements of all the transitions—high-high, high-low, and low-low—as previously discussed. A schematic diagram of one such electronic system, controlled by wires buried in the pavement, is shown in Figure 13. Considerably more experimentation along these lines can be expected in the next several decades, and facets of the techniques will no doubt be adopted sooner as driver aids. Full-scale adoption of automatic car control in the immediate future, however, seems unlikely because of both high cost and reliability problems.

A radically new approach to the interurban problems which clearly emphasizes speed is that of the Levacar announced by Ford. This approach avoids the speed limitations of conventional wheels and tires by dispensing with them entirely, and allowing the car to ride effectively on an air bearing. An artist's conception is shown in Figure 14, and a section of the air bearing which makes the whole thing possible is shown in Figure 15 (9). This system in its present form is clearly designed for the case of the high-high transition only. However, it meets the essential requirement of really high speed and is realistic in that it avoids the limitation of wheels and tires, but does provide positive guidance by means of rails. An analysis of requirements and possible contributions for such a system (named the Autoline) has been reported (10).

A still more recent concept is one by Westinghouse. This one is particularly interesting in that it is specifically designed to meet the basic requirement of transport between areas of dispersed population. It provides the equivalent of the high-speed moving belt, but eliminates the belt by putting motors in the road and moving cars on sleds. Because it provides for moving the car as well as the passenger, it meets the transportation requirements for low- as well as high-population-density areas. Artist's conceptions are shown in Figures 16 and 17 (11).

Particular attention is called to Figure 17, which shows the special attention given to the problem of loading and unloading cars. This operation has been taken out of the control of the driver once he gets his car parked on the pad.

Even running out of gas or having a flat tire can't interfere with the loading operation. Similarly, because the motive power for the entire system rests in conventional highly perfected ordinary induction motors, reliability should be maximized.

As in the case of the Levacar, this concept seems to be realistic in that it meets essential requirements and seems also to be technically feasible. The big unknown lies in the economics, and this in turn depends on the traffic load.

A number of proposals which seem to meet the speed requirement of the interurban transportation problem have been discussed. A few comments on the hazard problem are in order.

First, an agreed "hazard scale" is needed in this field as much as the decibel scale was needed in the communications industry a few decades ago. It would seem that it has been adequately demonstrated that in the safety field more "talk" will continue to be unproductive unless it can be placed on a quantitative basis. It is really surprising that at this late date the transportation industry has not really tried to come to grips with this problem.

Since coming to Detroit I have had repeated occasions to cogitate about this situation. Why is there public apathy with respect to the seat-belt argument? Why, where there is strict enforcement, will drivers slow down to save their licenses, but not to save their own lives? What is the purpose of and the effectiveness of the holiday week-end safety campaigns? Do I dare take my family to northern Michigan resorts on holiday week-ends? If not, why spend tax money on resorts and roads?

The situation is most confusing. Surely the average driver also finds it so, but like a persistent but untutored poker player, a driver soon develops a sound intuition in matters of probability. Let's look more closely from this probability point of view at one of the questions previously raised—namely, why will drivers slow down their driving speed to save their licenses, but not to save their lives? The explanation now becomes quite simple. In gambling, the expectation is equal to the product of the probability of the occurrence and the payoff. The driver in the present example correctly assesses the probability of occurrence of a major accident as small, but with strict enforcement, the probability of loss of license as high. Thus he acts in strict accord with his assessment of the expectation—which, of course, may or may not be correct. If it is incorrect, it is we who owe him more and better and more usable information.

In the absence of quantitative hazard information that the average driver, of whom I consider myself one, probably sizes up the situation somewhat as follows: Motor accidents are only one of the kinds of accidents to which a mortal is exposed, and accidents are only part of the total hazard. This is clearly shown by the kind of information in Figure 18, and is known intuitively by the average driver. When motor vehicle accidents are reduced to the point where they are comparable to or smaller than other competing hazards—buried in the general noise level, so to speak—one might expect that they would no longer be of major concern. We know that this is not the case.

A possible, and even probable, explanation is as follows: We are all inclined to accept some irreducible, low, truly unavoidable residual accident rate with reasonably good grace. Our driving experience, however (particularly the "near misses," which we all experience), convinces us that in addition to this unavoidable hazard there is an additional hazard due to the "crazy" or "aggressive" driver. It is this additional hazard which is resented.

If this two-term hazard point of view is accepted, a number of psychological reactions become understandable. First, it accounts for the fact that each driver assumes that traffic officers are hired to protect him against "the other guy." Second, in regard to the public attitude toward optional safety devices such as seat belts, it is found that they, too, are primarily for protection against the "crazy driver," who should not be on the road anyway. Thus, in the opinion of the average driver, such safety devices appear as an added expense and added inconvenience in lieu of protection he feels he is already paying for—and he reacts accordingly.

Qualitatively, a theory of this kind seems to fit most of the available facts and it might be worth exploring farther.

In conclusion, I have enjoyed immensely this frank and free discussion. As mentioned in the beginning, I am not an authority on highway transportation. Thus I realize I may have overemphasized the questions without giving all the answers.

This is my way of protecting status as a reasonably competent and sophisticated amateur, and I don't want to lose my amateur standing.

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As We Go Forward

PYKE JOHNSON, Chairman, Highway Research Board

You have heard of some of the fascinating changes which lie ahead as the trained minds of our country grapple with tomorrow's problems. It is my part to talk about some of the things which are being achieved today in the laboratories, the classrooms and the field; findings which are having and will continue to have a profound effect upon our ways of living and upon our ways of making a living.

Forty years ago, when Thomas H. MacDonald conceived the idea of a Highway Research Board, road research was largely a matter of testing materials. The building of highways was then a matter of getting our rural folk out of the mud. Today, as MacDonald foresaw it would, the problem has become one of getting ourselves "out of the muddle."

As we go forward, we can no longer be concerned solely with physical questions, important as they are. The safety and economy of those using the present fleet of 74 million motor vehicles in the United States obviously depends on the constant improvement of the driver, the vehicle, and the road. But, the size of today's transportation problem enforces a need for an analysis of the human motives which lie behind the use of the vehicle, as well as the study of the man or woman at the wheel.

In addition, large issues affecting our social, cultural, economic and financial structure are at stake. Enormous investments in highway transportation resulting from the popular acceptance of the vehicle, rest upon its growing use. New markets lie ahead for industry as continued research develops new and better products. Our national defense is deeply involved.

As our population increases, the use of land for transportation in the rural and in the rapidly growing metropolitan areas becomes of greater moment. All of us in America want comfortable homes, good schools for our children, a decent place to worship, good hospitals and recreational areas; in a word, a good society wherein we can pursue our several ways with freedom as long as we do not transgress upon the public interest. In this view, transportation is a vital tool to an end.

The expanding pattern of movement which the gasoline engine has brought with it challenges the present form of our cities, our transportation services, and even the structure of our local divisions of government. A transportation service built upon the 10-mile daily travel of horse and buggy days cannot conceivably meet today's needs when time rather than distance has become the chief criterion of movement. We must build and rebuild, shape and reshape our plans to encompass today's demands. More, we need to plan as far ahead as we can see to keep the home and the marketplace of tomorrow up to the standards we want for our children as well as for ourselves.

To reach this "new frontier" will require the kind of pioneering spirit which made America great in the olden days when we were still in the process of making our country what it is today, the best place in all the world in which to live. It will take all the imagination which sound engineering planning can give: it will take the energy of youth, the wisdom of age, the skill of the scientist, the practical hard-headed knowledge of the doer, and the understanding of the body politic, you and me. At all times, there will be needed the work of those dedicated men and women who in the public service, in the universities or in industry, are devoting themselves to research.

Although it is but a part of the whole, highway research has already made great contributions to the present well being of our citizenry. As we go forward, it will do more—much more.

A few years ago, the Executive Committee of the Highway Research Board, recognizing the need for a systematic approach to the great issues underlying modern transportation, named a group of top men in the field to make a cold appraisal of the field for broadened research. In doing so, they had the full support of their parent body, the National Academy of Sciences-National Research Council.

At once this group began a year-long study. They contacted the men of all of the disciplines and skills represented in the National Academy of Sciences.

They interviewed the specialists in the U. S. Bureau of Public Roads. They talked with the men of the state, city and county highway departments. They dug deeply into the files of the several departments of the Highway Research Board with its well-balanced representation from public, academic and industrial disciplines. They called upon related organizations in the fields of planning, safety, traffic, the law, and finance. They looked at industry, where they found amazing results were being secured in electronics; in photogrammetry; in new data processing and computing systems; in the development of new vehicles, materials, and techniques; and a thousand other products and methods.

Out of this national survey came Special Report 55, popularly called the Holmes Report after the chairman of the committee, E. H. Holmes, head of the Research Division of the Bureau of Public Roads and a man both of knowledge and imagination. Out of it came, too, a critical and comprehensive forecast of things that need to be done in the decades ahead.

Nineteen areas were assigned top priority for highway research at an estimated added cost of $34 million for a 5-year program. This is only the beginning of a broadened program, going far beyond physical research, which will give all of us better roads at lower costs and at savings many times its cost in blood and tears as well as in hard dollars and cents.

Already, although the report has only just been issued, it has generated a vast new interest in what highway research can do for Mr. and Mrs. Average Citizen. It has stirred those men in business who draw their sustenance from catering to the public as manufacturers, distributors, or suppliers of services of one kind or another. It has attracted the interest and support of leading men and women in the field of public opinion, whether they are in the media, in the law-making bodies of the land, or in trade or civic bodies.

Over the years, the American Association of State Highway Officials has been a solid supporter of the work of the Board. When the great "Operation Road Test" at Ottawa, Illinois, was decided upon by the highway engineers some six years ago, they called on the Board to conduct the work in order to assure complete, detached, scientific objectivity in getting at the facts for their later use in formulating policy.

Further, AASHO and the Bureau of Public Roads have financed the Research Correlation Service of the Board. In this operation trained men constantly circulate among the highway departments, keeping them apprised of research developments everywhere and in return learning from them what new problems are arising.

At its annual meeting in Detroit in November 1960, AASHO went further. There the highway administrators recorded their support for a continuing revolving fund amounting to some $2½ million annually from which new highway research projects are to be financed. Final action awaits referendum by the states. But high in the list of priority will be continuance of the tests initiated at Ottawa in the form of satellite studies by each of the states based on the varying soil, weather and economic conditions which face them. These extensions will be needed to translate the Test Road results into usable facts for the individual states.

As another event of more than passing importance, the National Academy of Sciences last summer held a month-long conference at Woods Hole, Mass., on the subject of Research in Transportation. This event, sparked by Dr. Bronk but under the immediate chairmanship of Harmer E. Davis, 1959 Chairman of the Highway Research Board, brought together a selected group of men from the universities and the Academy. They listened to representatives of the various forms of transportation delineate the day's problems in rail, highway, air, water and pipeline movements, as well as the effect of the pattern of movement upon people. In their final report, the group found that research could be of great value in all these fields. Of most interest, perhaps, to the Highway Research Board was the emphasis placed on the problem of living and moving in urban areas.

The whole question of urban transportation has been under detailed consideration by the Board and the highway engineers for some years.

AASHO has just recently established a

new standing Committee on Urban Transportation Planning and undoubtedly some cooperative research involving the state highway departments and the Highway Research Board will be in this important area where currently too little is known.

The interest of the National Academy of Sciences in the broader social, political, financial and economic aspects of the total problem of urban development should have a real bearing on the job of getting at the underlying problems which face us.

It is well to keep in mind that in the realization and development of the huge program outlined in the Holmes Report, the Board will continue to perform its traditional task of coordinating and giving broad direction to the major phases of the highway research program.

Among the new research projects just favorably reported on by an ad hoc committee of the Board is one for a full investigation into the problem of de-icing bridge structures. Little understood as yet by the driving public, but of deep concern to the highway builders, is the rapid accumulation of ice on bridges in all parts of the country. Divorced from the warm earth, these structures quickly become points of hazard to the motorist in times of cold weather. To protect him, various materials are used which melt the ice but which tend to corrode the bridge.

It will take concentrated effort to correct this fault, but once done millions of dollars will be saved in construction and maintenance costs. Skid resistance on normal pavements is a related subject.

In a totally different area, scientists are developing electronic machines which will simulate driving conditions, so that the behavior of motorists under unusual traffic or highway conditions may be tested. Next month in Santa Monica, Calif., a conference will be held to determine potential research uses of such a simulator. Traffic simulation goes hand in hand with this work. Traffic flow is already being studied in cooperation with the mathematicians of the National Academy of Sciences and university and other research organizations.

The simulation area is a new one; not enough is known yet about it to justify definite forecasts. But the best brains in the country will be assembled to analyze the possibilities and to see how they can be developed. The potential is indeed great.

The effect of traffic on the driver's nervous tension—highly important to his safety—is under review. Here machines measure his galvanic skin response.

In the field of economics, broad studies are needed and are under way. What, for example, does an expanding highway system mean as opportunity for expansion, relocation or initiation of business, residential or industrial activity?

What can be done to provide all-weather surfaces for the millions of miles of lesser roads in the United States? Every one of these lanes carries people to market, to school, to church. The men who can make travel safer and easier over these by-ways will make a great contribution.

The mineral aggregates necessary to build roads, and the soils whose natural properties suit the requirements of road builders, are becoming scarcer. Some day science will find the way to improve the properties of native materials, the clays and shales. Probably the result will be reported first at one of our meetings.

Research is vitally needed on methods of controlling land use at interchanges, and in areas surrounding access points, to assure development consistent with the most desirable land and transportation needs.

Studies are revealing the interaction between transportation and land use, and hold promise of establishing how transportation facilities not only serve but also shape the community.

The part played by the law takes us into the social sciences, as do many other phases of the problem.

Among the most important of our tasks is that of bridging the gap between the scientist and the layman. Necessarily, the work of the scientist must be expressed in technical papers that frequently are incomprehensible to the layman. Yet work done in the public field in the United States can only be financed and applied when the public—you and I—appreciates what it means to us to such an extent that we are ready to pay for it.

For the first time, during the past year the Board has had the services of a group of men skilled in the art of putting technical documents into the language of the man on the street, then seeing to public dissemination of the material.

So the story goes. The whole gamut of human emotions, desires, needs, is run as we look forward into the future.

Back of all this is a human story. Dr. Frank Baxter has well said:

"Let us, O Lord, never forget that what we do, is done to human beings: to men, women and children--and not to faceless statistical puppets."

Then let me add to what Dr. Baxter has said: that in the field of highway research what is being done is not being done by faceless puppets but by devoted men and women.

Over all the years, the success of the Highway Research Board has been that it has followed the precepts laid down by Thomas H. MacDonald. In numerous conversations, he used to underline the point, strongly, that research must be done where the research brains are: that normally in times of peace, at least, they cannot be arbitrarily summoned to a central point and told to do a specific job. Only an "Operation Road Test" permits concentration. "Instead," he was wont to say, "we must make of the Board a forum where voluntarily the men and women in research can come together to compare notes on progress with others in the same profession."

As time has gone on, the wisdom of his precepts has been more than justified by the results. Today, the Board has six departments and three special committees covering many broad phases of research. Each has a chairman of top reputation in his field who serves without compensation.

Under those men we have 82 committees engaged in the constant study of the ever-growing field of highway research. Each committee has an average of 12 men, all recognized specialists in various areas who come together annually to give us the benefit of their own findings and to exchange ideas in the advanced areas of highway research. Nationally recognized as authorities in their own field, because they are men of science, they are little known to the general public, who are the beneficiaries of their work.

Here again, they serve on a voluntary basis. Many come from key positions in the universities of the land. Others are from the laboratories of industry. Still others hail from all branches of government. Each is contributing in his own way to the total sum of knowledge of all of us, doing his or her bit in the job of making a better America.

As the years have gone by, the number of individuals involved has grown steadily. Today, the Board meetings number many men in high positions in many foreign countries, each intent on taking back to his own land something of the feeling of this great voluntary, and typically American, cooperative movement.

In the background, also unheralded and unsung, is the staff of the Highway Research Board headed by a dedicated public servant, worthy successor to his teacher Roy Crum but, like him, known to but relatively few outside the immediate circle of his work. That man is the Director of the Highway Research Board, Fred Burggraf.

The work load has tripled in the past twelve years, yet the eight men of Burggraf's staff have carried on, growing grey in the public interest, rewarded chiefly by their own knowledge of a job well done. Ahead of us is the need for greater recognition of these men, for understudies who can begin to pick up part of the load. With that fact of life goes also the other fact that as highway research grows in complexity new skills and disciplines must be incorporated into the work.

Historical Highlights of the Highway Research Board

FRED BURGGRAF, Director, Highway Research Board

The National Research Council was established in the Spring of 1916 when President Wilson requested the National Academy of Sciences to organize the scientific and engineering forces of the United States for the purpose of defense.

In May 1918, by executive order, President Wilson perpetuated the National Research Council and attached it to the National Academy of Sciences, which was incorporated by Congressional Charter and approved by President Lincoln on March 3, 1863.

Also in 1918, President Wilson issued another executive order directing all governmental agencies to cooperate with the National Research Council. That gave every governmental department executive authority to cooperate.

In October 1919, Professor A. N. Talbot and Dean Anson Marston, representatives of organizations in the Division of Engineering and Industrial Research of the National Research Council, met in Chicago with Thomas H. MacDonald, Commissioner of the Bureau of Public Roads, and Clifford Older, President of the Mississippi Valley State Highway Department Association, to discuss the importance and necessity for the immediate inauguration of a national program for highway research and a listing of the highway research agencies. They also recommended that a subcommittee of the Engineering Division be appointed to cooperate in the coordination of the various highway research committees.

On October 26, 1920, Chairman C. A. Adams of the Division of Engineering and Industrial Research addressed a letter to the governing boards of certain national organizations, federal and state departments, and educational institutions, stating the need for highway research, outlining the projected committee organization, and inviting representatives to a conference for the purpose of completing the organization. At that meeting, held November 11, 1920, an Advisory Board on Highway Research was organized and by-laws were adopted.

Thomas H. MacDonald was present at that historic meeting and outlined the need for highway research and supplied the financial support which made possible the launching of the Board's program.

C.D. Curtiss, one of the three here at the head table who attended this organization meeting, went to New York to draft the later adopted by-laws. The other two were A.T. Goldbeck and Pyke Johnson.

The first Annual Meeting of the Board was held in the Engineering Societies Building, New York City, on January 16, 1922. Professor W.K. Hatt, on leave from Purdue University, was Director. Professor Anson Marston of Iowa State College was Chairman of the Executive Committee, which consisted of only five members, of which Mr. MacDonald was one.

The attendance at this first Annual Meeting was 30; only four committee reports were presented and discussed. These were: (1) Character and Use of Road Materials, Chairman H.S. Mattimore; (2) Economic Theory of Highway Improvement, T. R. Agg, Chairman; (3) Structural Design of Roads, Chairman A. T. Goldbeck, who is here with us tonight; and (4) Tractive Resistance, Chairman, Major M. L. Ireland, Quartermaster Corps of the Army.

The total annual budget for 1922 was $13,500. The Bureau of Public Roads gave $12,000, the Engineering Foundation gave $1,000 and the National Research Council the remaining $500.

The salary scale at that time was also interesting. The Director recommended the appointment of an Assistant Director at a salary of $3,000 a year and a competent stenographer at $1,800 per year.

The early records show that as far back as 1923 the Director was having budget difficulties. Following the statement of a needed annual budget of $35,000 was this comment: "$15,000 is in sight, leaving $20,000 to be raised by the Ways and Means Committee."

At this 40th Anniversary Meeting, let us review very briefly some of the historical highlights in 10-year intervals.

THE 1920'S

Professor Hatt, on leave from Purdue University, was the Director in 1922 and 1923. C.M. Upham, who is present here tonight, was Director from 1924 to 1928. Upon Mr. Upham's resignation in 1928, Roy W. Crum became Director.

The average attendance at the Annual Meetings during this first 10-year period was 225, with an average of 20 papers or reports presented during the two-day session.

There were reports on wind resistance to vehicles, tire wear, cost of vehicle operation, the question of not being able to freeze water when desired in certain soils, and the ability to freeze it in others, impact tests on concrete, traffic analysis, and grading of top soil mixtures for local roads. Also, reports of the tests at the Bureau of Public Roads Arlington Experimental plant, of the Bates Road Test in Illinois, and the Pittsburgh tests in California. Two Special Reports were published entitled, "Economic Value of Reinforced Concrete" and "Low Cost Improved Roads," both of which were financed by industry.

During the latter part of this decade a proposed program of highway research was introduced by Messrs. MacDonald and Crum, the two men we have honored by placing their pictures in the program before you. A few of the problems considered of most importance were:

1. Soils and their characteristics, particularly as subgrades.
2. Low cost roads of adequate service character.
3. Highway transport utilization and attendant problems.
4. The planning of highway systems.
5. The financing of highways.
6. The effects of heavy vehicles, and relative taxation or other charges for highway purposes.

Some of these earlier papers had interesting titles in light of later developments, such as: "The Services of Psychology to Problems of Traffic Control," "Application of Aerial Mapping to Highway Construction," and "The Demonstration and Dramatization of Research." The last was a real public relations contribution.

The "News Letter," as a medium to acquaint public, academic and industrial representatives of developing research matters, was inaugurated during the late 1920's.

Active representation was established through contact men with the state highway departments and more than 100 universities and colleges. That arrangement, in an expanded way, is still in existence today.

"Without the sympathetic and active support of the Bureau of Public Roads, through Mr. Thomas H. MacDonald, the Board could not have functioned." This statement was taken from the minutes of the Executive Committee in the late 1920's.

The name was changed from the Advisory Board on Highway Research to the Highway Research Board. The Executive Committee membership was increased from six to eleven.

One last item, which probably does not rate as a general highlight but which had a pleasant impact on a future career, was my own initial affiliation with the Board as a Special Investigator in 1929.

THE 1930'S

The average attendance at the Annual Meetings during this 10-year period was 405, compared with 225 in the 1920's. The average number of papers and reports presented was 59, against the 20 of the previous decade.

Considering the economic depression during the earlier part of that decade, these figures reflect an interesting growth.

Some of the noteworthy innovations during this 10-year period of Mr. Crum's directorship were the following:

1. Creation of a Research Information Service (1930).
2. Initiation of the synopsis procedure for all papers in Proceedings (1931). This is still being used.
3. Initiation of the Highway Research Abstracts publications series (May 1931). There were about two issues yearly until 1934; since then they have been issued monthly. The fine facilities of the Bureau of Public Roads library have over these

Thomas H. MacDonald
1881 - 1957

Roy Winchester Crum
1885 - 1951

many years been a great reservoir of current source material for these Abstracts. The assistance received from the library staff and the courtesies shown our own librarian are greatly appreciated.

4. Acceptance of joint sponsorship of the Bartlett Award with the American Association of State Highway Officials and the American Road Builders Association. Thomas H. MacDonald was the first recipient (1931).

5. Establishment of active representation through contact men with 53 different cities in 27 states (1931).

6. Establishment of the first joint project with the American Association of State Highway Officials, on a study of the laws, funds, organization and technical practices relating to roadside development.

7. Initiation of a general policy of charging for issues of Proceedings, which were free up to this time (1934).

8. Reorganization into Departments and Committees for the division of the work (1935). Previously there had been no Departmental division.

9. Creation of a new Department of Soils (1935).

10. Establishment of a joint arrangement with the American Association of State Highway Officials for the purpose of conducting and maintaining a highway research census (1936).

Interest in soil mechanics and soil stabilization reached the degree that a two-day session was devoted to this problem at the 1938 Annual Meeting. The most recent knowledge of soil science in relation to its application to the problems of highway engineering was contained in the 40 papers and reports presented.

In addition to the regular yearly Proceedings, the following special publications were issued during this decade:

1. Use of Rail Steel Reinforcement Bars in Highway Construction.

2. The Use of Calcium Chloride as a Dust Palliative.

3. A Symposium on Research Features of Flexible-Type Bituminous Roads.

THE 1940'S

The average attendance at the Annual Meetings during this 10-year period was 640, compared with 405 in the 1930's and 225 in the 1920's. The average number of papers and reports presented was 82, against 59 and 18 in the 1930's and 1920's, respectively.

To avoid the national emergency congestion in Washington caused by World War II, the Board abandoned a long-established custom by leaving Washington and holding its next four assembled Annual Meetings in the following cities:

1941 - Baltimore, Maryland
1942 - St. Louis, Missouri
1943 - Chicago, Illinois
1945 - Oklahoma City, Oklahoma

The 1944 meeting was scheduled to be held at Cincinnati, Ohio, but was canceled at the request of the Office of Defense Transportation. The papers and reports prepared for this meeting were published in a Proceedings but there was no "assembled" Annual Meeting that year.

Briefly, the following are some of the highlights of the decade:

1. Establishment of the Highway Research Board Award (1940) and the Highway Research Board Distinguished Service Award (1948).

2. Inauguration of the procedure whereby individuals or companies may affiliate with the Board on a non-voting basis (1940).

3. Establishment of a series of lecture courses on highway economics jointly with universities and colleges (Iowa State, Texas A and M, and Utah University). The purpose of these courses was to acquaint the highway administrators and engineers with the fundamentals of economics which apply in the operation of highway systems (1940-41).

4. Initiation of a series of Wartime Bulletins on timely subjects. The object of these pamphlets was to disseminate in useable form the best available information on those phases of highway technology in which common practice had not become established or in which practice had to be modified during the war. There were several of these issued (1942).

5. Establishment of a joint committee with the American Association of State Highway Officials on a study of maintenance personnel (1946).

6. Initiation of a joint research project with the Bureau of Public Roads and the Asphalt Institute on a flexible pavement track.

7. Inauguration of the Research Correlation Service (1945).

8. A study of vehicle size and weight vs gasoline consumption and travel time in Pennsylvania by the Committee on Economics of Motor Vehicle Size and Weight.

9. Studies of actual traffic situations with special instruments by the Committee on Vehicle Characteristics.

Research Correlation Service

Establishment of the Research Correlation Service was the greatest single event in the life of the Board as far as carrying out more effectively the purposes laid down by the founders and accounts, in a large measure, for the accelerated progress during the last 15 years.

This service is financed on a yearly subscription basis by the state highway departments and the Bureau of Public Roads. The Board agrees in these contracts to "collect the available information concerning past, current and proposed research work relating to highways and highway transportation, of the Federal Government, State highway departments, colleges and universities and research agencies; study and correlate the information by means of individual and group conferences and committee activities; prepare reports and make recommendations based thereon; and disseminate such information, reports and recommendations to the subscribers to the Service and to other highway research agencies."

The Board has five professional engineers, each of whom is specializing in one or more of the branches of highway technology represented by the six departments under which the technical committees operate. A considerable part of the time of these engineers is spent in making periodic visits to state highway departments, colleges, universities and other agencies engaged in highway research.

These engineers also serve their respective departments and committees with technical assistance.

THE 1950'S

During this decade there was a phenomenal growth in the Board's activities.

The average attendance at the Annual Meetings during this 10-year period soared to 1,610, compared with 640 in the 1940's. The average number of papers and reports presented was 186, against 82 in the 1940's.

Some of the major special projects which were financed from special donated funds during this period were:

1. Road Test One-MD.
2. The WASHO Road Test.
3. The AASHO Road Test.

The total cost of these three projects was about $28.5 million, with the last accounting for about $27 million.

4. Non-Rigid Pavement Design.
5. Effect of Wind Stresses on Bridges.
6. Intergovernmental Relations in Highway Affairs.
7. Calcium Chloride Stabilization.
8. Relationship of Parking to Business.
9. Laws Study.
10. Urban Research.
11. Study of Friction Piles for Highway Structures.
12. Research Problems of Mutual Interest and Concern to Users and Producers of Asphaltic Materials.
13. Special Study for Department of Defense on "Effects of Military Aircraft on Airfield Pavements."
14. Arrangement of an exchange of soil scientists between Russia and the United States.
15. Although not financed by special funds, Special Report 55, "Highway Research in the United States, Needs Expenditures and Application," must be included.

During this decade publications production increased from 2,000 pages to more than 5,000 pages per year.

To keep pace with this increased activity the Executive Committee membership was increased from 11 to 21, with the new members representing disciplines which were deemed necessary.

During the latter part of this decade the Department of Economics, Finance and Administration sponsored three Special Workshop Conferences on (a) Economic Impact of Highway Improvement; (b) Economic Analysis Relating to Planning Location and Design; and (c) Highway Construction Programing.

Earlier in this decade (May 15, 1951) we were saddened by the death of our beloved Director, Roy W. Crum. A unanimously adopted motion by the Executive Committee on June 12, 1951, contains these words:

"In the words of Ralph Waldo Emerson, 'An institution is the lengthened shadow of one man.' For nearly a quarter of a century this has been true of the Highway Research Board of the National Research Council. Its outstanding progress since 1928, when he became its Director, has been due, more than to any other factor, to the quiet, modest, effective leadership and practical vision of Roy Crum.

"His integrity, friendliness, modesty, open-mindedness, industry, fairness, determination and resourcefulness have won universal respect and have endeared him to all—young and old—who have in one way or another been associated with him."

Also to perpetuate his memory the Executive Committee changed the name of the Highway Research Board Distinguished Service Award to the Roy W. Crum Distinguished Service Award. It was my exceedingly good fortune to have been closely associated with him for 15 of the 23 years he was directing the growing work of the Board. His fine human qualities and his deep understanding of the significance of highway research which I came to know so well will always be an inspiration to me.

Also, in April 1957, at the death of Thomas H. MacDonald, we lost a loyal and devoted friend. It was largely through his efforts in cooperation with the Division of Engineering and Industrial Research of the National Research Council and interested highway transport groups that the Advisory Board on Highway Research was formally organized on November 11, 1920. He sustained it during those difficult pioneering years when the vital role of research in highway transport was not widely recognized and continued to do so during the 34 years he was U. S. Commissioner of Public Roads.

FORTY YEARS OF PROGRESS

I hope it is realized that in the short review given here justice could not be done to the over-all accomplishments of the Board.

It has been said that "research knowledge in highway engineering grows by accretion." In the unfolding 40 years of activity of the Highway Research Board no single discovery has claimed leading notice. Each year has seen a thin layer added to the pearl of assured knowledge placed at the service of highway transportation through the activities of the large company of technical men who made possible the Annual Meetings of the past.

There is little doubt that these meetings over the past 40 years have contributed greatly to the development of the men who have advanced the technology of highway transport to its present high level.

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. This provision accounts for the close ties that have always existed between the ACADEMY and the government, although the ACADEMY is not a governmental agency.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.

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