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T R F

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Highway Equipment Innovation for Improved Public Service and Carrier Profits

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I. INTRODUCTION

Your Chairman has asked that I discuss with you a systematic approach to highway equipment innovation that will provide for both improved public service and increased carrier profits through more efficient transportation. I particularly welcome this assignment because it fits a number of my personal philosophies:

A. A principal obligation of management is to sponsor and to direct change. Perhaps the basis for this point is a deepseated belief that there is a definite value in the creation of change, namely the opportunity to bring progress.

B. Another belief is that research and development are most beneficial when they seek technical objectives in tune with management objectives based upon market research and economic analysis. In the establishment of project priorities, we are seeking projects that are of major importance (big plums), that offer promise of major improvement (juicy plums), and that appear to offer high odds of success in the near future (ripe plums).

In this regard, project selection might well recognize some lessons learned from experience concerning the relationship of long range programs to short range programs. It is true that greater savings usually come with changes in method than from improvements in existing practices. However, when a basic change requires the development of new technology, the odds of achievement of the envisioned goals are reduced. Therefore some companies feel that they get the most return for their development dollar when they work on projects that can probably be realized in a 2-5 year period.

1. There is a constant need for carrier managements to apply industrial engineering techniques (ahead of equipment design) in systems analysis of carrier operations to identify cost problems or cost reduction opportunities, and to "visioneer" and evaluate alternative methods. The documented evaluation of alternative methods is frequently the only way to resolve the tug-o-wars of opinion and give management a basis for "action" decisions. Later, industrial engineering techniques are helpful to coordinate implementation of approved programs, and to control operations through the development and monitoring of performance measurements.

2. Similarly, there is a continuing need to utilize market research to identify and focus upon the major areas of opportunity for volume

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and profit improvement. It also is the best method for determining carrier performance in terms of market penetration.

There is a parallel need for each carrier to emphasize economic analysis of the part that transportation plays in the total logistics of its customers. As carrier mergers develop larger companies, there may be a need for reorganization of marketing staffs to apply adequate management attention to each segment of the market in order to maintain the close relationship to its customers that was a trademark of the smaller highway carriers during their growth years. A well defined marketing approach may also prove a basic tool in the efforts of for-hire carriers to compete with private carriage.

In this regard, we would do well to recognize that low transportation charges are of major interest to carrier customers. However, frequently higher charges can be justified if a special service brings a greater cost reduction, or solves some practical problem, in another logistics area. One example might be the reduction in packaging and materials handling (approximately 80c/cwt) when bulk transportation is offered. A second example might be the trade-off between lower inventory maintenance costs for higher transportation charges for smaller volume shipments. Thus it can be recognized that for both carriers and customers cost reduction is only a contributing objective, with profit and investment return as primary objectives.

Thus I should like to suggest that we begin our discussion of innovations in highway equipment with a brief review of the relative importance of various volume aspects and economic factors of trucking, and especially intercity trucking. This approach will help us establish operating objectives and lead us into a discussion of current and future innovations in equipment design. It will also introduce a problem that will plague us throughout this limited discussion, namely the immensity and complexity of the subject when compared to the time and space available. It will become obvious that there is a wide diversity of objectives, priorities, operations, and equipment needs in accordance with differences in customers, commodities, volume, territories, etc. in the various segments of intercity highway traffic. Thus we cannot hope to cover all equipment innovation. However, a broad guage review may serve to illustrate a systematic approach to equipment innovation, as well as to highlight a limited number of specific, new equipment concepts. The review will tend to emphasize several lessons:

1. The large portion of intercity freight economics involving origin, intermediate, and destination terminal operations.
2. The close interrelationship of intercity line-haul operations with associated terminal operations.
3. The variance in equipment solutions depending on route, terminal, customer, and shipment volumes.
4. The need to provide greater cubic capacity in line haul operations, and at the same time to provide smaller line haul units.
5. The need for equipment innovation and regulatory logic in reducing empty mileage.

6. The opportunity for equipment innovation to reduce material handling, etc. through unit-load and bulk concepts.
7. The opportunity for innovation in auxiliary equipment for environmental control and enroute processing.

RELATIVE IMPORTANCE OF HIGHWAY OPERATIONS

To begin a review of this complicated subject we might well follow Napolean's suggestion to "Engage, then plan." Since most discussions of highway operations focus on common carriage of general commodities, we too will begin here. The following two tables will serve to establish several relationships between the volume of general commodities and special commodities, common and contract carriage, intercity and local flows and between regulated and non-regulated operations. While the basis of comparison of freight revenues may not be as appropriate as truck loads, tonnages, tonmiles, etc. for some phases of equipment marketing or for highway planners, it is an appropriate consideration for highway carrier managements and initial equipment marketing studies.

NATIONAL INTERCITY FREIGHT REVENUES*
ICC Regulated—1966—Dollars (000,000)

	Intercity Transport			
	Common Carriage	Contract Carriage	Misc. Other (inc. Cart.)	Total
GENERAL COMMODITIES	$5,523	$ 31	$592	$6,146
SPECIALIZED COMMODITIES				
Household Goods	456	1	54	511
Liquid Petroleum	410	21	12	443
Motor Vehicles	255	123	19	397
Refrigerated Solids	158	13	5	176
Building Materials	75	22	4	101
Heavy Machinery	82	1	8	91
Agricultural	38	8	2	48
Refrigerated Liquids	15	2	0	17
Films, etc.	11	0	0	11
Other (Bulk, Chem, etc.)	830	171	46	1,047
TOTAL COMMON CARRIERS	$7,853	$393	$742	$8,988
TOTAL CONTRACT CARRIERS	14	341	22	377

NATIONAL FREIGHT VOLUMES**

	Intercity Ton Miles	Revenue	Total
ICC-Regulated	39%	39%	22%
Non-ICC-Regulated	61%	61%	35%
Total Intercity	100%	100%	57%
Local			43%
Total			100%

Note: For-hire trucking represents 77% and private trucking represents 23% of total intercity ton-miles of manufactured goods.

* From American Trucking Association data (approx. 80% of Total)
** From Transportation Association of America data

Importance of Terminal Operations

Similarly, most discussions about highway equipment focus on line-haul equipment, so we too will begin with a review of the economic relationships of this factor to other factors in intercity freight.

The president of one of the major common carriers has frequently stated that his company generates over 92% of its transportation revenues from LTL shipments, or those under 10,000 lbs. And my experience has indicated that many, if not most, of the successful trucking companies gain the majority of their revenues, and profits, from their LTL business. This appears true even though most carriers are loosing money on the smaller range of LTL shipments (i.e. 800 lbs. and under) because of an unrealistic pricing structure. Therefore it behooves us to look at the relationship of the line haul factor to the total picture in the intercity transportation of LTL. While costs will vary with the territory and the mix of freight, with the characteristics of the pick up and delivery, dock, and line haul operations, and with the capability of management, the following chart (and Exhibit 1) appears representative of carrier costs in LTL operations.

LESS-THAN-TRUCK-LOAD SHIPMENTS

			PER HUNDREDWEIGHT 15 lbs/cu. ft., 2400 cu. ft., 85% Capacity Utilization			
		Per Mile Dollars	250 Miles $	250 Miles %	500 Miles $	500 Miles %
LINE HAUL						
Fixed Veh (Depr., Fin., tax)		.08	.07	3	.13	6
Variable Vehicle		.15	.12	7	.25	11
Maintenance	.06					
Fuel, Oil, Tax	.05					
Tires	.03					
Other	.01					
Driver & Expenses		.13	.11	6	.21	10
		.36	.30	16	.59	27
Overhead		.04	.03	2	.07	3
		.40	.33	18	.66	30
Empty Mileage (1/4)		.10	.08	5	.16	7
		.50	.41	23	.82	37
TERMINAL						
Pickup & Delivery @.45x2		.90		49	.90	40
Dock Handling @.20x1.5		.30		16	.30	14
Clerical, Claims, etc.		.21		12	.21	9
		1.41		77	1.41	63
TOTAL		$1.82		100%	$2.23	100%

The revenue volume data indicate the importance of purely local traffic. Further, the above cost data indicate that terminal operations represent the bulk of common carrier general commodity costs for the shipment distances normally served by highway, (even when the shipment does not pass through an intermediate terminal). Thus equipment design of terminal pick-up and delivery equipment and of line-haul equipment (which is also used for terminal pick-up and delivery) must endeavor to facilitate terminal operations. The data also indicates the relative importance of some of the major cost factors which can be improved with the equipment concepts discussed below.

A further perspective on line haul versus terminal costs can be gained from the following chart and Exhibit II, which presents a review of volume

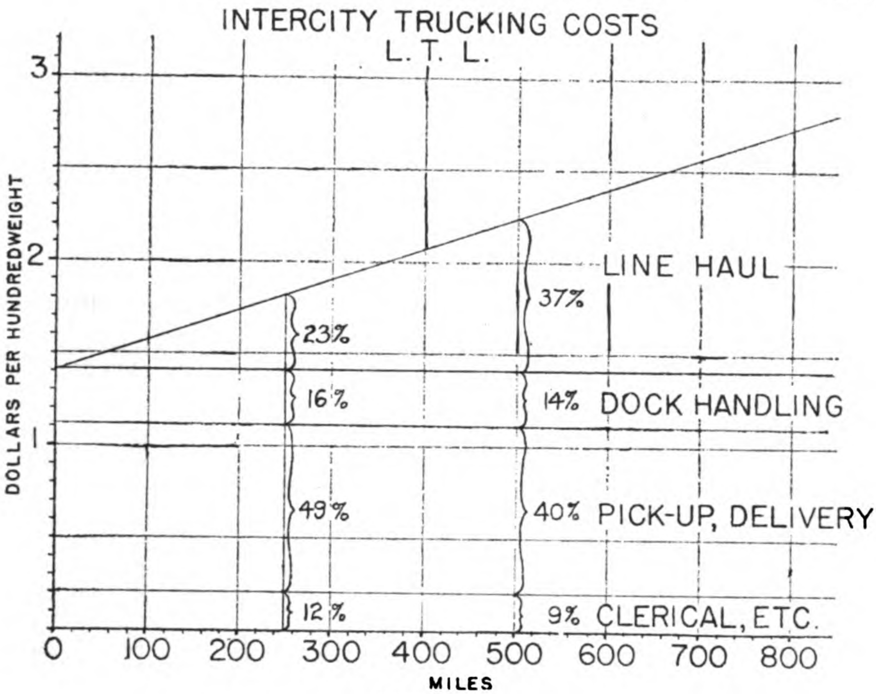

EXHIBIT 1

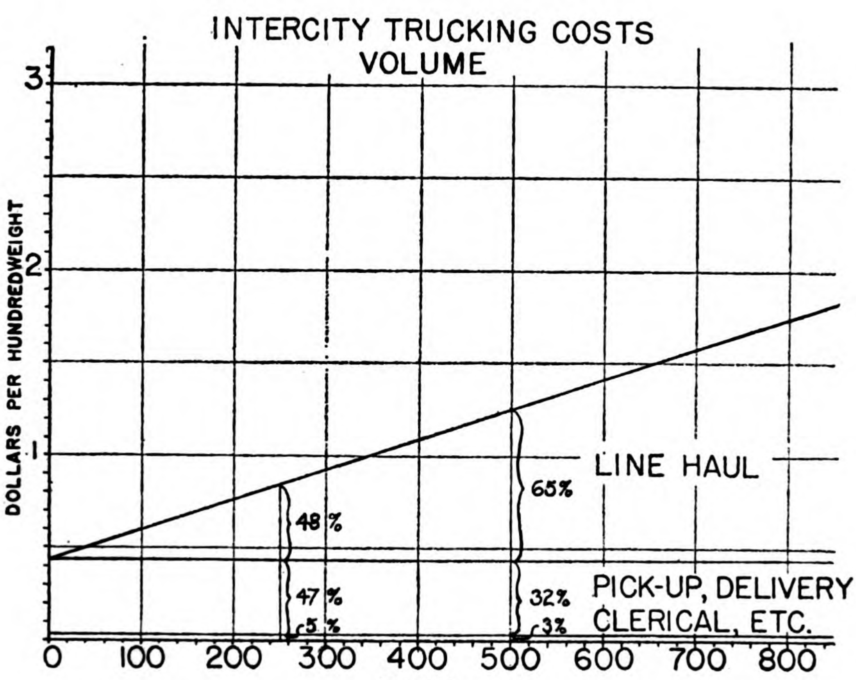

EXHIBIT 2

freight shipments (i.e. from 10,000 lbs. to truckload). For simplicity, the density of the freight has been held constant. While volume and truckload movements represent the smaller portion of general commodities common carriage, these costs are more representative of the line-haul to terminal ratios of some specialized carriage costs, and of contract and private carriage costs.

VOLUME SHIPMENTS

		Per Mile	PER HUNDREDWEIGHT 15 lbs/cu. ft., 2400 cu. ft., 85% Capacity Utilization 250 Miles		500 Miles	
		Dollars	$	%	$	%
LINE HAUL						
Fixed Veh (Depr., Fin., tax)		.08	.07	8	.13	10
Variable Vehicle		.15	.12	14	.25	20
Maintenance	.06					
Fuel, Oil	.05					
Tires	.03					
Other	.01					
Driver Expenses		.13	.11	13	.21	17
		.36	.30	35	.59	47
Overhead		.04	.03	4	.07	5
		.40	.33	39	.66	52
Empty Mileage (1/4)		.10	.08	9	.16	13
		.50	.41	48	.82	65
TERMINAL						
Pickup & Delivery @20x2			.40	47	.40	32
Clerical, Claims, etc.			.04	5	.04	3
			.44	52	.44	35
TOTAL			$.85	100%	$1.26	100%

ALTERNATIVE APPROACHES AND CONCEPTS

When we evaluate alternative concepts on the primary basis of carrier cost (or profit or ROI), we find it helpful to calculate in terms of unit commodity costs. Here we are concerned with the spread of absolute costs in the numerator as they are divided by various factors in the denominator. Thus there are three principal approaches to the reductions to unit costs:

1. First is the design of equipment which will allow the complete elimination or bypassing of a function. For instance, the development of methods for combining smaller pick-up cargo units (20-28 feet) into larger line-haul units and then breaking them down into local unit size for delivery may allow the bypassing of origin and/or destination dock operations. This is discussed in greater detail in a later section of this paper.

2. The second would be to reduce the absolute costs illustrated above. Thus innovation in equipment materials, design or construction might reduce the original price of tractors, trailers, tires and auxiliary equipment. Similarly the cost of fuel, oil, lubricants and spare parts might be reduced. However, constantly increasing demands for more so-

phisticated equipment make this appear unlikely, and a greate deal of innovation would most certainly be required to reduce basic labor costs or taxes.

On the other hand, innovation does offer the possibility of savings in lower consumption of fuel and in maintenance costs for both power and refrigeration equipment. Similarly, improved insulation can reduce the cost of refrigeration in all areas of price, fuel, and maintenance of refrigeration. In addition, the simple lining of cargo van bodies with spray polyeurethane considerably reduces leaks, condensation, and resultant maintenance and claims costs.

3. The third approach would be equipment innovation which increases the denominator (over which we spread absolute costs), and which thus reduces the unit cost of the absolute costs. Two examples would be the spread of fixed vehicle costs like annual tax costs or like annual depreciation and financial costs (or the annual freight revenue required to achieve a specified ROI after taxes when a time value of money is considered) over more miles per year. Another example would be larger loads to spread the wages of a local or line haul driver. Here we are concerned with a sort of unit efficiency derived from:

   a. Increased capacity in terms of
      —Life (years, miles, trips)
      —Power (pulling, refrigeration, etc.)
      —Weight
      —Cube

   b. Increased utilization in terms of
      —Miles per year (as burdened by the empty mileage factor)
      —Loads per year
      —Revenue per year

Greater Cube With Smaller Units

One of the most significant and advantageous developments in highway equipment in recent years is the expansion of the double-bottom and triple-bottom concept (i.e. trailer trains). This expansion is noted both in application and in state highway laws as the concept is adopted in the eastern states. While it may appear that the approach is simply to reduce unit line-haul costs by spreading absolute costs over larger loads, there are other basic, but subtle, advantages.

There is a basic need for greater cubic capacity in package freight operations because of the low density of general commodities (12-15 lbs/cu. ft.). Further, there is a continuing trend to lower densities as light weight materials and specialized packaging are applied by industry. In the first example (By-gone operations) in Exhibit 3, we see the old standard trailer with 2400 cubic feet capacity, and we note that the maximum load can approach 50,000 lbs. But the maximum cubic and weight capacities match at a cargo density of 21 lbs/cu. ft., considerably in excess of the density of the general commodity average. Since it is a basic fact that transportation efficiency is achieved when both weight and cubic capacity (as limited by engineering

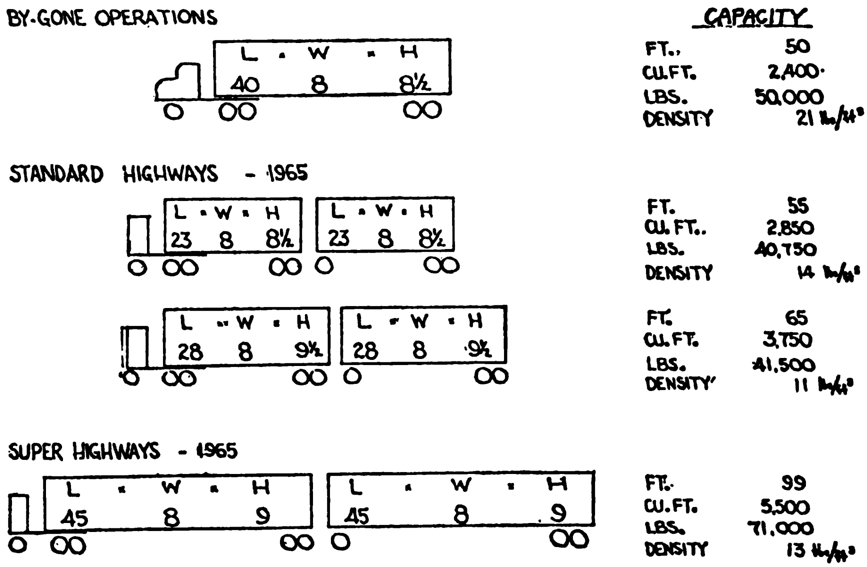

EXHIBIT 3

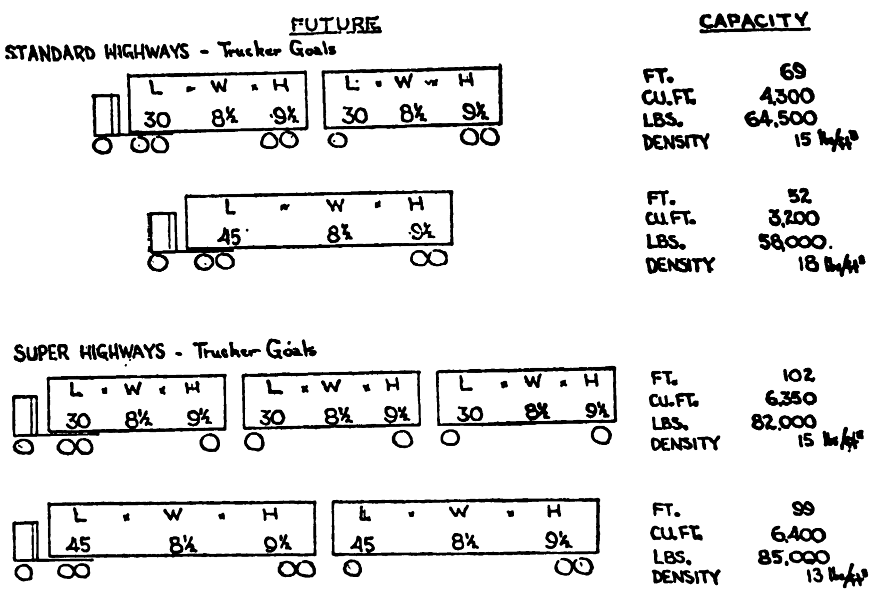

EXHIBIT 4

law, etc.) are utilized, there is a need to obtain additional cube in highway units. Further, it appears that standard trailer trucks are most competitive with railroads when package freight approximates 19 lbs. per cubic foot.

The shape of trucking and railroad cost curves makes railroads increasingly competitive above or below that figure, and especially so at the lower densities. Greater highway cube would alleviate this situation for highway carriers.

Additional cube can be obtained by modifying standard trailers in the different approaches that have been proposed. Widening to 8-1/2 ft. would be the least effective, with an increase of only 6%. Raising the overall height to 13-1/2 ft. would increase cube by about 12%. Some years ago we arranged to use smaller wheels and tires to reduce the floor height (without wheel boxes) and cube was increased by 12-18%. This approach could be further progressed if front wheel drives were developed to the point where tractor rear wheels could be reduced and the deck in drop frame trailers eliminated. There would be auxiliary advantages in local P&D operations (especially with straight vans) where lower floors would facilitate loading and unloading. Recognition of these advantages might encourage engineering efforts to resolve remaining problems of weight on the combined steering and driving front axle. While other proposals of increasing cube and reducing wind resistance involve attaching belly pods under trailers, the attendent complications have prevented progress in this direction.

The final approach to increasing cube lies in the direction of lengthening the trailer. A five foot increase would result in a cube increase of approximately 12%. This has been done in the case of automobile hauling where the density approximates 4-8 lbs/cu. ft. But for many operations, longer trailers would raise problems in local P&D operations. A major factor would be maneuvering in major cities (and some cities restrict overall length in the central areas to 33 feet except for special permits). Another factor would involve both service and cost because of the elapsed time required to "strip" inbound loads at terminal docks with the efficient one-man-crew concept. Finally, the size of the line haul unit is larger than many customer logistics systems or marketing practices will utilize. Therefore separate shipments may be required to fill out the trailer, thus involving either higher P&D or dock costs.

Thus we find an apparent paradox which calls for larger cubic loads but smaller units. The answer seems to lie in the direction of highway trains, either of trailers or individually powered units. The western "tandem" or "double bottom" is being more widely adopted, and even expanded into "triple bottoms". Length limits for these units have gradually been increased to 28 feet and some carriers hope for 30 foot limits.

Some basic problems in trailer-trains have existed, however, and development is being continued. While tractors are available with adequate power to pull heavy tandem loads in hilly country, it is difficult to utilize this power through the traditional tandem drive axles. Sometimes there is not enough weight in the nose of the lead trailer to obtain enough traction. And sometimes the tires "shuck" their trends under the high shear stresses. This latter problem is similar to that of aircraft propulsion designers in World War II. Larger reciprocating engines were possible, but the power could not be absorbed by the propeller concept and new jet propulsion designs became necessary. In the highway field, some innovators are endeavoring to provide booster power in the trailer dollies, utilizing smaller, remotely controlled engines. Here, some engineers envision turbine tractors generating electricity for electric drives in order to provide efficiency and to avoid gear-shifting problems.

One of the very intriguing solutions to powering highway trains is the development of connectible self-powered units called Wolf-Wagons. These units can be operated as individual units on local operations and simply, but effectively connected for line haul operations. On the highway, the accelerators, brakes, etc. in the rear units are controlled by a driver in the lead unit. Thus power that is adequate for local operations can be combined with similar units so that it is adequate for line haul operations. This type of unit is especially suitable for efficient line-haul to moderate sized towns where several drivers can be added for local operations (either common carriage or distribution of commodities) without the need to have standby tractors. In a similar way, these wagons can be combined in units of two, and operated by only one driver, for the reduction of "stem" driving costs in local P&D operations. The current problems of slightly higher price and cost can be largely overcome with increased production volumes and through the savings they generate.

The expansion of the highway trailer train concept also poses problems of guidance and safety, especially in stopping. While these trailer trains (and Wolf Wagons) are equipment engineering matters, highway engineering problems are also created. Should there be special trailer-train lanes? Should complete trucking terminals adjacent to the super highways be sponsored at major metropolitan centers, instead of the current small, inefficient parking areas? Terminals where trailer trains could be disconnected for local operations and where interchange and dock operations could be readily accomplished. But these are highway problems which will be discussed by the other panel members.

This trend to 24-30 foot highway units is playing "hobbs" with the 20 ft. and 40 ft. intermodal and international container standards. Yet there is sound economic logic in these sizes concerning domestic highway transport which is many times more important than the international traffic. Nevertheless, some of the same advantages ascribed to van containers hold true for smaller highway trailers. One example involves the direct loading of road haul units with intermediate size loads, thus by-passing terminal dock operations. The LCL cost example shown above illustrates the current practice of by-passing dock operations 25% of the time as the larger 5,000-10,000 lb. shipments are loaded in 35-40 ft. road haul units. This practice might reach 50% with the expanded use of smaller trailer train units.

Another use of the smaller units to by-pass docks would be exploitation of the high volume available to certain merchandising companies, consolidators, forwarders, and carriers. Where enough volume exists in an origin city to provide an efficient delivery operation in one zone of the destination city, a delivery size unit can be loaded at the origin terminal and the destination terminal by-passed. With exceptionally large volume, it might even be possible for pick-up in a large origin city to be segmented into separate operations with one unit doing all the pick-up for the ultimate distribution delivery zone, thus by-passing both terminal docks for LTL shipments. Smaller line haul units also facilitate make-and-break operations at intermediate terminals.

Frequently it is possible to by-pass these docks and yet have good line-haul load factors.

Greater Cube for Local Units

A number of intercity carriers are saving terminal labor through the use of city semi-trailers (24-30 ft.) which offer greater cubic capacity than straight trucks. The savings are not necessarily intended to come from larger loads to spread "stem" driving etc. Instead the cube is wasted to provide an aisle for individual access to the various items of cargo (including internal containers or unit loads of various sorts). Thus inbound freight can be "stripped" at the carrier's dock and immediately cross-dock loaded into the delivery unit without flooring the freight for subsequent route-stop sequence loading. Similarly, cube for cargo access can be used during pick-up to sort the freight by outbound routes (or destinations) into internal containers (mobile bins or cargo binders). Under this concept, dock work involved in unloading the local pick-up can be reduced as much as 80%.

New Concepts in Cargo Access

Another approach to the provision of cargo access mentioned above has involved a more complicated design which spread the walls of the trailer when it was off the city streets at carrier or customer docks. Once again, its very complicated design spelled trouble and cost, so it has not yet been accepted.

Nevertheless, there is a great need to provide greater access to all the cargo in a vehicle, especially in combination pick-up and delivery runs where access through only one door would require constant rehandling and shifting the freight. This is especially true in the handling of large internal containers. A good example of a desireable solution is the design of local soft drink and beer trucks. Here a multitude of sliding side doors or panels open to allow a full case to be off-loaded and an empty case to be reloaded in the same spot without shifting neighboring items. A more complicated proposal involves a floor chain-tow concept which indexes desired containers or pallets to the rear door in "merry-go-round" style. And nose loading is bringing P&D savings.

There are significant specialized needs for simple access which might even make it worthwhile to provide dock facilities for side unloading of unit loads. Perhaps several examples will serve to illustrate this point, and at the same time comment on the value of the "key stop" or "night deposit" concepts. A "key stop" related to the practice in chemical and petroleum trucking where a driver makes a delivery without any coincident receiving functions by the consignees. This is similar to the delivery of home heating fuel oil. In commercial operations it allows two shifts to utilize the trucks about 20 hours per day.

One example might be the delivery to farms of containers of "prescription" feeds or fertilizers. Another example might be the distribution or collection by a common carrier of containers of "peddle" freight and mail to small town cartage men for subsequent delivery, or after prior pick-up. A third might be the night time P&D of freight to major buildings in metropolitan areas where streets and alleys are congested in the daytime.

Internal Containers and Unit Loads

The values of smaller transportation units, but without adverse effect on materials handling, have been discussed above. A further development of this concept involves the use of various types of unit loads and internal containers to facilitate pick-up and delivery. The advantages herein relate to the use of unit loads to improve the elapsed time, labor expense, and equipment utilization by speeding the loading and unloading of freight. Carrier pricing that truly reflects the economics of volume and of unit loads will tend to encourage shippers to consolidate minimum shipments into moderate size unit loads.

The above considerations have stressed the importance of local trucking and terminal dock operations because of their prominence in intercity freight costs as illustrated in the LTL and Volume examples above. Here it might be appropriate to mention that P&D management techniques may be as valuable as methods changes and associated equipment innovations. Great savings in P&D costs can be obtained when industrial engineering type labor standards are utilized to plan and control P&D operations. There is also the need to stress the need to shift a share of attention to local highway problems from the current over concentration on intercity highways.

Now these P&D concepts may well have further effects on equipment innovation. While the use of unit loads is increasing, attempts are also being made to reduce the cost of the unit pack (pallets, etc.). There appears to be a wide range of solutions, from pneumatic glides (which may involve floor air jets) to take-it-or-leave-it floor grooves to accomodate travel and load picking by multi-pronged fork trucks. Floors are also being designed with rollers or ball bearings like freight aircraft. Where mobile bins, cargo binders, or some other types of unit loads are used, the vehicle design may require plastic guides and securing devices in the walls.

Increased Weight Capacity

As with cubic capacity, the trucking industry is still on the steep part of the tonnage economy-of-scale curve. In this matter, the industry has real engineering, economic, and regulatory limits concerning increased weight loads. I should like to leave discussion of these roadbed problems to the panel members to which they have been assigned. However, it appears appropriate to briefly discuss the equipment approaches to these problems.

The roadbed weight limits are concerned with two problems. One is the weight allowable on bridge spans. Perhaps the only equipment approach would be longer units, possibly tandems. The second problem involves the concentration of loads on the roadway surface or panel. Here the equipment industry has made considerable progress in tire design and in the utilization of additional axles and tires to spread the load. In Michigan you can frequently see tractors with tandem drive axles and 8 drive wheels, plus a trailing four wheel axle and double width tire on each steering wheel. These units pull a semi-trailer with 3 axles, and 12 tires. This in turn is followed by a full trailer with 3 axles, on a dollie with 3 axles, a total of 24 tires. Thus the unit has a grand total of 50 tires capable of carrying a capacity load of 132,000 lbs.

Perhaps only two other approaches need be mentioned here. One is the use of light weight equipment construction materials in non-usual parts, such as engine blocks, so as to increase pay-load. A second is the use of internal bracing to accomodate two and three tiers of uncrated items which could only be floor loaded in a standard trailer.

The High Cost of Empty Mileage and Poor Utilization

A great opportunity for equipment innovation exists in the high cost of empty mileage. Frequently a return load might be found if the equipment could handle it. An example might be the hauling of general commodities in one direction and liquid bulk on the return (or even the blending in each direction to balance weight and cube). Solutions to these problems are readily available through collapsible rubber tanks and belly tanks. There is a need to bring to regulatory agencies (which have placed barriers in the way of this progress) a sense of the high public cost of empty mileage. It appears unreasonable for governmental agencies to continue to exercise in this matter their traditional tendencies to protect the status quo and proprietary (risk) investment.

The opportunities for cost reduction through the development of multiple-use, specialized equipment extend beyond the reduction of back haul to the greater utilization of equipment in seasonal industries, or for sporadic flows. An example would be the pressure differential equipment which handles fine dry-bulk commodities one day and liquid bulk the next. Or the general commodities van whose upper side wall panels are hinged to fold inward and down to the floor to form flow sheets for unpackaged agricultural and industrial products. In some instances, the center floor boards at the base of the trough are removed to reveal a longitudinal unloading conveyor.

Auxiliary Equipment

The subject of auxiliary equipment is a broad area of innovative activity, and it is the final area of equipment innovation which we will discuss briefly today with only two examples. Developments in refrigeration and heating equipment is progressing with more efficient units, better insulation (including more easily cleaned interiors), and more effective air circulation. However, we hear more and more about total environmental control through the use of inert gases. Once again we find that the answer does not lie in the simple direction of minimum equipment cost. While the use of liquid nitrogen for refrigeration maintenance (vs original cooling) may be more expensive than mechanical systems, its prevention of the usual evaporation of 4% in weight of meat makes it a worthwhile system. With a recognition of the importance of this type of consideration, developments which combine mechanical refrigeration with various mixtures of inert gases is being pursued to provide enroute quality controls for a wide range of fruits and vegetables.

The "key stop" concept was mentioned above for more efficient use of equipment in local distribution. However, there is a crying need for final development of equipment that will provide for dry bulk commodities a metering and certificate printing service similar to that which is already available for liquid bulk. Several efforts, which involve various approaches to weighing, appear on the brink of making "key stop" services available for products like flour and sugar in the LTL qualities that have previously required either small unit packaging or medium sized internal containers.

The Value of Documented Evaluations

Perhaps the above discussion will serve to illustrate a few of the many equipment developments that are underway. There remains only the need to stress the value of evaluating equipment concepts with sound engineering and system economics analysis prior to the expensive phases of hardware design and construction. This approach appears especially desirable in resolving differences between the two traditional viewpoints, namely the reliance on standard equipment produced in large volume at low cost and the reliance on more specialized equipment whose higher original prices may be offset through various logistics savings.