ROAD AND/OR TRANSPORT PRODUCTIVITY

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ROAD AND/OR TRANSPORT PRODUCTIVITY

The principle thrust of WHI's forty-two plus years of research for and technical assistance to the trucking industry in the western portion of North America has centered on the increased productivity required to meet the economic challenges associated with major geographic obstacles and regulatory constraints. In recent years, we're observing that not only has the character of the obstacles and constraints changed but also that the requirements for increased productivity in many cases are becoming the key to industry survival. Late in 1979, WHI produced a film, "More Productive Trucks," documenting extensive past research, highlighting promising productivity concepts, and pointing to the challenge that is now being experienced. The film script incorporated several observations that are increasingly more relevant.

The first observation is a basic statement of cultural fact, "Almost everything we need -- food, clothing, shelter -- we buy from someone else or they buy from us so we are constantly exchanging goods which have to be transported." This statement has obvious modal and intermodal ramifications but, within the context of the film, the rhetorical question posed is "Do we have any alternative -- any economically viable alternative -- to truck transport over our existing highway system?" The sound track continues: "If not, and it certainly appears that we do not, then we must either multiply the number of trucks on our highways or make each truck more productive."

These observations tie directly into the highway geometrics and operations subject of the session today and ultimately into the overall theme of this conference. Our focus is on those factors which affect productivity -- productivity of the facilities, productivity of the vehicle, and productivity of the overall transport system.

The "old" highway engineering philosophy of build more -- more new, more strength and more capacity seems inevitably coupled with the trucking industry response -- "need more and need bigger." Having lived in both camps, I empathize with the never ending dilemma presented providers, on one hand, and users on the other. As a result, this presentation is not a technical research report but rather a plea for rethinking the process and procedures of the past with a view toward defining a "better way to do business." The presentation will briefly review those factors which impact facility productivity, those that influence goods transport productivity and some of the choices which favor one, the other, neither or both.

PRODUCTIVITY IMPLICATIONS

Given that the word "productivity" can be defined as the quality or state of being productive, what does being "productive" imply? Webster offers a number of possibilities including: having the quality or power of producing, effective in bringing forth or forward and yielding or furnishing results or benefits, especially in abundance. Going further, a thesaurus referenced suggests that the word infers characteristics which include: creative, innovative, constructive, and profitable. This suggests then that anything "productive" should have the capability to effectively bring forth a net return of benefits through creative and constructive use.

Extending my amplified definition more specifically to transportation productivity is difficult, however, since facilities, use, and user elements are all included and all inclusive. In fact, transportation productivity is an economy-related variable that can, and likely will, be evaluated differently as it relates to specific circumstances.

The frame of reference for this presentation is U.S. experience and conditions. It's well known that in the late 1940s national recognition was being given to the fact that the then existing highway system was woefully inadequate to accommodate the needs of interstate travel. The response was the creation of a virtually all new, "more productive" system of controlled access highways.

The Interstate System, as it's referenced, changed "the way we do business" in America -- probably not the cause but rather the facilitator of an evolution in the basis of our national economy. Unfortunately, the planners, engineers, and economists involved in framing the Interstate System failed to foresee either the tremendous vehicular capacity demands that have developed in the major metropolitan areas or the necessity to properly design for and accommodate the phenomenal growth in the heavy vehicle population.

Robert A. Waterman, Jr. in his recent book, The Renewal Factor (1), offers the following assessment of the current U.S. situation: "There was a time in America when, if you depleted what you had, the solution was easy. You moved somewhere else, tapped into a new set of resources, and started fresh. You walked away from the old structure. That doesn't work anymore. There's nowhere else to run; the frontiers themselves have been exhausted -- with one exception, the challenge of renewal." Mr. Waterman's book and this comment are directed to corporate America. However, many of the observations he makes are, I believe, more universal in application and particularly relevant with respect to transportation in general and goods transportation in particular. Hang on to the reference to "renewal"; that's a concept which I'll come back to.

TRANSPORTATION PRODUCTIVITY

As suggested earlier, transportation productivity might be "measured" by the ability to effectively bring forth a net return of benefits through the creative and constructive use of the tools available. I view these "tools" as the road or highway system on one hand and the user vehicles and systems on the other. The fact that the two "tools" are independent with each encompassing a wide range of fragmented interests makes the important elements of interdependence particularly difficult to deal with and, if you will, to harmonize.

My intent is to focus on those particular elements of interdependence between road and transport, i.e., "goods" transport, productivity. I would suggest that, aside from the policy and administrative concerns of each, there are a significant number of practical physical concerns which interact to establish the boundaries of potential productivity. Any resolution of these concerns finds expression in the form of the size, weight, and operational restrictions established to define and control expected use.

ROAD AND TRANSPORT PRODUCTIVITY

Taking things backwards, I'll touch briefly first on those factors which impact goods transport productivity. I'll spend a little more time on road productivity and then conclude by offering a suggestion for eventual resolution.

Transport Productivity

The thesis of this presentation, if one can be found among the ramblings, is that size and weight limits, as they presently exist, impose engineering constraints on vehicles which are not well correlated with either facility capabilities or transport service requirements. Further, in virtually every operating environment the overall productivity potential of transport vehicles is of little general concern and is therefore constrained by the lowest common denominator of jurisdictional size and weight limits.

In the past few years, a notable U.S. attempt has been made to "certify" two basic vehicle configurations for nationwide uniform operation -- and these only on a system of "designated" highways. The current product is a confused goods distribution network with innumerable loose ends.

The Canadians, armed with recent research data and a prior public commitment, are attempting an even more ambitious project of vehicular productivity reconciliation which embraces more and differing vehicle configuration types. But even they acknowledge that all units are not appropriate on all roadways.

In Europe, the Organization for Economic Cooperation and Development (OECD), has formed a scientific expert group on "Truck Routes and Networks." The purpose is to gather, quantify, and articulate the special needs and requirements associated with their international road and transport productivity problems.

The basic stumbling blocks in each case will be found, I believe, in: the absence of "solid" vehicular/road interactive performance data, the inability of current control mechanisms to address performance issues, and the prevalence of the "not invented here" syndrome. Numerous independent research projects and certainly the more integrated and highly successful CANROADS effort are increasing performance awareness and beginning to make substantial inroads in the data base problem. Symposia such as this are certainly helping to explore the problems and to establish the credibility necessary for more widespread acceptance of performance criteria. However, the regulatory policymakers will likely continue to assume the role of "chief vehicle design engineer" while the technical community continues to work on getting its act together. The inevitable result is inappropriate facilities, inappropriate vehicles, or both.

Road Productivity

The concept of maximizing road productivity hinges on the ability to precisely define and harmonize the various attributes which are influenced by vehicle use demands. Generally speaking, this involves interrelating operational requirements, pavement requirements, and bridge requirements for various operating environments. The subject is much too broad to attempt to even comment on in detail, but a few specific concerns will be mentioned in each of the three areas noted.

Operational requirements. I would define operational requirements so as to encompass both geometrics and traffic control systems including safety and efficiency implications. In a sense, geometrics largely determine what can be safely accommodated and control systems determine how effectively they can be utilized.

Automobiles and trucks obviously influence roadway geometrics requirements in differing ways. This presents a twofold problem in that the differences have neither been fully quantified and integrated into design standards nor are they static. A 1984 study (2) entitled "Geometric Design of Exclusive Truck Facilites" conducted by the Texas Transportation Institute (TTI) states:

> "Geometric design was addressed initially because it affects right-of- way limits, operational efficiency, safety, and construction costs. Current roadway design policies largely reflect those outlined in AASHTO's green book. However, these policies assume that the majority of the design traffic will be automobiles, with a relatively small percentage of large trucks."

Therein lies the problem. Whether or not exclusive truck facilities are the focus, the magnitude of the truck population on many facilities today (and increasingly more in the future) definitely establishes truck requirements as the controlling basis for safe operation.

Figure 1 presents the TTI assessment of geometric features and related vehicle characteristics. While I would take issue with some and perhaps suggest others, the listing is instructive for three reasons: first, the critical vehicle characteristics, what ever they might be, need to be fully defined in terms of the controlling performance criteria that might characterize existing legal vehicles. Second, these controls need to be "wrestled" out with manufacturing and user interests to establish acceptability and continuing viability. Third, the final standards should be used as the basis for system-related, system-wide hazard signings and upgrade programs. Further, if the facilities vs. changing requirements cycle is to be interrupted, the agreed upon performance envelope must be firmly established as the basis of acceptability for all new vehicles; i.e., performance standards.

Vehicle-related characteristics noticeably lacking in the TTI list are those related to vehicle dynamics. The University of Michigan Transportation Research Institute, (UMTRI), has an established high profile in the

Figure 1

Geometric Features and Related Vehicle Characteristics

GEOMETRIC FEATURE	RELATED VEHICLE CHARACTERISTIC
SIGHT DISTANCE:	
Stopping Sight Distance	Braking Distance Eye Height
Passing Sight Distance	Vehicle Length Acceleration
HORIZONTAL ALIGNMENT:	
Superelevation	Vehicle Height (C.G.)
Degree of Curve	Vehicle Height (C.G.)
Widths of Turning Roadways	Vehicle Length Vehicle Width
Pavement Widening on Curves	Vehicle Length Vehicle Width
VERTICAL ALIGNMENT:	
Maximum Grade	Weight to Horsepower ratio
Critical Length of Grade	Weight to Horsepower ratio
Climbing Lanes	Weight to Horsepower ratio
Vertical Curves	Eye and Headlight Heights
Vertical Clearance	Vehicle Height
CROSS SECTION ELEMENTS:	
Lane Widths	Vehicle Width
Shoulder Widths	Vehicle Width
Traffic Barriers	Vehicle Mass and C.G.
Side Slopes	Vehicle Height (C.G.)

area and has contributed substantially to recognitiion of the various factors involved (Figure 2). To their credit, UMTRI has worked diligently in both the industry and the regulatory arenas. Perhaps the most significant outgrowth of the attention generated is a new Society of Automotive Engineers (SAE) subcommittee on truck and bus safety dynamics -- a group dedicated to developing standard procedures for the various test maneuvers implied. The SAE work is indeed timely since the International Organization for Standards (ISO) is also currently working in this same subject area. I would be less than candid if I said there were no industry reservations with respect to how some of these test maneuvers relate to roadway operations and/or geometrics. However, the process of developing standard test procedures should, hopefully, address these issues as well.

Heavy vehicle operation in the urban area is an emotion-charged source of irritation for U.S. auto drivers, particularly when these operations coincide with the commute period. There is considerable doubt whether any standard of truck handling and performance would be judged satisfactory when traffic service drops below level "C." On the other hand, geometric constraints, congestion, and traffic controls all present problems for truckers as well.

I bring this up for two reasons: 1) the cost of making necessary geometric changes in the urban environment tends to be prohibitive and 2) several recent studies have shown that in the real world, heavy vehicle operations may not be as constrained or constraining as engineer's turning templates might suggest. That's not to say that the off-track problem is insignificant, but rather that, unless traffic levels are prohibitive, other drivers do a good job of anticipating and providing room for short-duration lane encroachments required in the absence of adequate geometry.

I particularly want to call attention to a project, report, and free computer program completed by Wisconsin DOT (3). The principle thrust of that project centered on how to differentiate between intersections that require only minor modification and those that must be rebuilt to provide acceptable levels of service. The product is a methodology which facilitates the decision-making process and helps sort out the most effective site-specific modifications short of complete reconstruction.

The heart of the methodology is a traffic gap acceptance model which replicates the cross stream traffic in five different stop sign control conditions. By comparing the calculated or assumed input value for an acceptable gap, the researchers were able to simulate conditions in which truckers would respond to gaps as low as four seconds. This ties back into traffic control and productivity through the WISDOT observation that:

> "...signalizing downtown intersections on the designated highway system can cause serious operational problems for both left and right turning long truck movements."

The point - traffic signals tend to be overused as the panaceas for every

Figure 2

Summary of Performance Measures for Benchmark Vehicles

Performance Measure
1. Maximum transient (low-speed) offtracking (ft) - 41 ft and 90°
2. Braking efficiency at 0.4 g's - Loaded - Empty
3. High-speed offtracking (ft) - 1200 ft at 55 mph - At last axle - At end of last unit
4. Rollover threshold (g's)
5.a. Critical speed at 0.3 g's (mph)
5.b. Steering sensitivity at 0.3 g's and 55 mph (radians/g)
6. Lateral acceleration response times - ramp step (sec)
7. Maximum rearward amplification

Source: Fancher, Paul S. and Mathew, Arvind, "A Vehicle Dynamics Handbook for Single-Unit and Articulated Heavy Trucks," University of Michigan Transportation Research Institute, May, 1987.

traffic control problem. If long truck turns are regularly required at geometrically deficient intersections, a traffic signal installation may favor neither road nor transport productivity.

Pavement Requirements. Pavement response to vehicular load and pavement "wear" are, in my observation, two of the most researched and talked about subjects that civil engineers know the least about. For example, pavement engineers will swear by the "4th power theorem" but have virtually no knowledge of what the dynamic tire footprint looks like, how the load varies within that footprint, or how these factors might have changed since 1959. The same can be said for suspension systems, their differences, and their improvements over time.

While the pavement tire interface is "the great unknown" that pavement researchers still need to look long and hard at, its becoming increasingly more evident that periodic dynamic load effects may actually define the upper bounds of pavement response requirements. Yet, while the concept of developing "vehicular performance" requirements for controlling demands made on pavements is intriguing, it appears more likely that "rules of thumb" based on crude empirical evidence will probably continue as the basis of pavement design ad infinitum. If so, I would place pavement design among those items that may or may not favor road productivity but will almost certainly adversely affect transport productivity.

Bridge Requirements. If you were to make a table of the factors which affect road productivity versus those that affect transport activity (Figure 3), you would likely find as I did that bridge capabilities hold the potential for activating virtually every transport productivity control mechanism. By and large, however, bridges by the very nature of the way they're designed are not often found to be a major constraint on normal road or transport productivity unless obsolesce, i.e., poor geometrics or short remaining design life, is a dominant characteristic.

The principal deterrent to transport productivity is normally found in the varying interpretive analyses of critical stress levels. This typically finds expression in "bridge formulas" or tables of allowable weight which have been used to "override" individual axle or axle group weight allowances.

In the U.S., Formula "B" (Figure 4) is still an element of general public policy, but is under attack from various user segments who believe they suffer from needless constraint. Recent attempts at reformulation are being viewed by road designers with chagrin, however, because more generous weight allowances for bridges would result in liberalizing axle loads and amplifying pavement effects. The dilemma created simply points to the need to "harmonize" those elements which determine road productivity and ultimately control transport productivity.

Conceptual Resolutions

The Canadians are positioned on the leading edge of applied research and have given us two very different models for resolving the conflict between

Figure 3

Potential Constraints on Road and Transport Productivity

Road Constraints \ Transport Constraints	Size and Weight Limits					Locational Constraints			Operational Compliance Checks	Operating Costs			Driver/Travel Time
	Length	Height	Width	Gross	Axle Wt.	Time	Place	Load		Axles	Tires	Tare Wt./Fuel	
Bridge Capabilities	-	I	I	I	I	-	I	I	I	I	I	I	I
Capacity (Vehicular)	-	-	-	I	-	I	I	-	-	-	-	-	I
Engineering Concerns (1)	-	-	-	-	-	-	I	I	-	-	-	-	I
Environmental Compatibility (2)	-	-	-	-	-	-	I	-	I	-	-	I	I
Geographic Conditions (3)	-	-	-	-	-	-	I	I	-	-	-	-	I
Geometrics	I	I	I	-	-	-	I	-	I	-	-	-	I
Incidents/Events	-	-	-	-	-	I	I	-	-	-	-	-	I
Maintenance Delays	-	-	-	-	-	I	I	-	-	-	-	-	I
Operations Control	-	-	-	-	-	-	I	-	-	-	-	-	I
Reconstruction Activity/Frequency	-	-	-	-	I	I	I	-	I	I	I	I	I
Surface Roughness	-	-	-	-	-	-	-	-	-	-	I	-	I
Weather Conditions	-	-	-	-	-	I	I	-	-	-	-	-	I

(1) Engineering Concerns - Construction Consistency
- Drainage Problems

(2) Environmental Compatibility - Noise
- Air Pollution

(3) Geographic Conditions - Water Table
- Soils/Materials
- Freeze/Thaw

(I = Interactive constraints on both road and transport productivity.)

Figure 4

FORMULA B

$$W = 500\left[\frac{LN}{N-1} + 12N + 36\right]$$

W = overall gross weight on any group of two or more consecutive axles to nearest 500 pounds.

L = distance in feet between the extreme of any group of two or more consecutive axles.

N = number of axles in group under consideration.

road and transport productivity. The first, the "Ontario Model," (4) established size and weight parameters that are critical to protect key infrastructure elements and allows industry innovation to guide vehicle development. The second, "the RTAC Model," (5) determines specific desirable vehicle characteristics and "rewards" vehicle developments which respond.

From my limited perspective, neither of these very constructive models appears to fully integrate all the elements of concern, however. Let me lay out an extemely oversimplified approach and then conclude by returning to Waterman's challenge. I would suggest the following four steps:

- Establish through research the specific vehicle-related parameters which are critical to optimum facility performance, i.e., road productivity.

- Cap regular operation (non-permit) size and weight limits at a level that insures legal operations within the bounds of optimum facility performance.

- Establish performance criteria for extra-legal operation so as to allow industry innovation with respect to the development of service-specific vehicles.

- Develop a special permit system that could "qualify" extra legal operations based on vehicle performance <u>and</u> insure operational compliance.

This is far out stuff with no established mechanism for implementation -- therein lies the challenge -- what Waterman alludes to as "renewal". Following is a string of quotations from Waterman's book, which, though taken out of context, make the point.

> "Facts are friendly. Facts that tend to reinforce what you are doing and give you a warm glow are nice, because they help in terms of psychic reward. Facts that raise alarms are equally friendly, because they give you clues about how to respond, how to change, where to spend resources." H. Schacht.

> "Habit breaking, the prerequisite for change and renewal, needs more than a simple decision. It takes motivation, desire, and will. Crisis can provide that, and all too often is the sole force for change." Robert Waterman.

> "Few things help us find meaning more than a cause to believe in or, better yet, about which to get excited....Renewers seem able to pick causes and communicate them in a way that conveys an element of risk -- of challenge, but not foolishly so." Robert Waterman.

What's your cause? Road productivity? Transport productivity? Neither, or both?

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