Planning Urban Access for Large Combination Trucks

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In Canada and the United States, as a result of liberalized regulations of freight motor vehicle weights and dimensions, there will be increasing pressure to provide urban access to large combination trucks. Although studies have recently been completed on vehicle performance, the effects of oversize vehicles under open highway conditions, and the identification of the highway network for their operation, it is essential at this time that a better understanding of the problems of urban access and possible solutions be acquired. Described in this paper is research conducted in the sociotechnical criteria and methodology for the definition and assessment of urban access policy alternatives. The criteria include the ability of oversize vehicles to use urban truck routes and terminals as well as the effects of such vehicles on urban access routes. To augment data available from published and unpublished sources, a questionnaire survey of transportation departments of urban areas, provinces, and states in North America was carried out. In this paper, following background summary, urban access issues are introduced and a utility theory-based methodological framework for the evaluation of access alternatives is described. Access policy options are defined and evaluated. Results of the evaluation process provide new insights into the development of solutions to the urban access problem. In conclusion, the innovative nature of the evaluation model, as well as some guidelines for the planning of urban access are highlighted.

A major government-industry cooperative research effort, coordinated by the Road and Transportation Association of Canada (RTAC) and the Canadian Conference on Motor Transport Administrators (CCMTA), examined the effect of variations in truck weights and dimensions on vehicle stability and control and on pavement loadings (*1*, *2*). The testing phase of the study has recently been completed. In addition to stability and pavement response studies, preliminary research results on industry impacts have been reported (*3*).

Presently, work is under way to develop regulatory principles. The first level of priority has been assigned to apply revised size and weight scenarios in regulating the tractor semitrailer and various configurations of double trailers (i.e., *A*-train, *B*-train and *C*-train doubles). Recommendations are expected to include a program of upgrading highway facilities.

Next in line would be regulations for extended length vehicles, namely rocky mountain doubles, turnpike doubles, and triple trailers. The rocky mountain doubles are double trailer combinations, with the lead trailer being 45 to 50 ft (13.7 to 15.2 m) followed by a short pup trailer of 26 to 28 ft (7.9 to 8.5 m). Turnpike doubles are twin 45 to 50 ft (13.7 to 15.2 m); trailers and triples are a combination of 26 to 28 ft (7.9 to 8.5 m) pup trailers. In all cases, trailer width is restricted to 8.5 ft (2.6 m).

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In the Canadian provinces of Alberta, British Columbia, Manitoba, Quebec, and Saskatchewan, at present, special rules and regulations apply for operating extra-length combination vehicles. These include specific permits applicable on specified routes. The conditions and routes allowed vary for different types of equipment.

In the United States, longer combination trucks are at present operating in 12 states and on 6 additional state turnpikes (*4*). The feasibility of a nationwide network for longer combination vehicles has been investigated pursuant to Sections 138 and 415 of the Surface Transportation Assistance Act (STAA) of 1982. Among other unresolved issues associated with a long combination vehicle network, local access is believed to be the most troubling aspect of the network (*4*).

In Canada, as well as in the United States, available evidence suggests that the trucking industry is switching to vehicles with the larger dimensions for truckload type of traffic and to longer combination vehicles based on the use of wider (8.5-ft) pup trailers for less-than-truckload operations (*3*, *5*). There is every indication that whenever and wherever regulations permit rocky mountain and turnpike doubles and triple trailers, the trucking industry will seize the opportunity to increase its use of such large trucks.

URBAN ACCESS ISSUES

Canadian road motor regulators and municipal governments have not so far clarified the extent to which large combination trucks are to be granted access to existing terminals and other points of loading or unloading. It is, however, commonly assumed that large combination vehicles will be granted a certain degree of urban access. In the United States, the STAA (1982) includes a provision for "reasonable access." According to this provision, " . . . states may not deny reasonable access to vehicles of the weights and linear dimensions authorized by the STAA (1982) between the National Network and terminals or service facilities" (*5*).

Clearly, there are opposing pressures at work. Trucking interests, especially those that are potential users of large combination trucks, are interested in access to their terminals and other major generators of shipments. Also, they are interested in avoiding any extra costs associated with urban access and reducing delays in serving major hub terminals. On the other hand, the urban community wants to avoid adverse impacts of urban access provided to such vehicles. The allocation of incremental costs of urban access routes for oversize vehicles is an unsettled issue.

For policy analysts and planners, the complex task is to balance the urban access (i.e., associated productivity gains in goods movement) against effects of urban access (e.g., costs of road improvements, safety, traffic disruption, and environmental impacts). Trade-offs are to be investigated between staging areas (for combination vehicle breakup) with virtually no urban impacts and options for permitting urban access beyond major highways.

It is assumed here that interchanges for the oversize truck entrance or exit either are adequate or will be modified. Our interest here is in urban access routes that link staging areas or existing or new terminals with major intercity highways.

METHODOLOGICAL FRAMEWORK

Previous authors have recognized the need for research in urban access issues and called for tools that treat these multi-dimensional socio-technical issues *(4, 5)*. In order to address the urban access problem, a methodological framework was defined (see Figure 1).

At the outset, characteristics of oversize combination vehicles (in terms of offtracking, backsway, braking, and blocking motorists' view) were noted. In the second step, the current practice of providing urban access for the existing large combination trucks was reviewed and outstanding problems were noted. The review of the practice of providing urban access included staging areas as well as access routes and terminals. Typical sources of information include recent reports on this subject *(6–8)*.

In the third step, a survey of transportation departments of urban regions and provincial and state transportation departments was carried out to obtain supplemental information about current practices of providing urban access and existing as well as anticipated problems. From the findings of Steps 1 to 3, a synthesis of future (potential) issues and value structure was carried out in Step 4. Access options were also defined in Step 4.

A utility theoretic evaluation model was defined in Step 5 for establishing the relative desirability of the various access options. In Step 6, applications of survey results and the utility-theoretic model were illustrated in the form of evaluating four access options, and inferences were drawn for urban access of large combination trucks. Highlights of the overall research project are presented in this paper.

SURVEY OF TRANSPORTATION DEPARTMENTS

A questionnaire type of survey was initiated to elicit current practice toward oversize vehicles, together with any changes in the parameters that the various agencies intended to implement or considered should be implemented to accommodate these vehicles.

The questionnaire was designed to obtain factual data as well as to quantify values of access criteria and related factors. Specifically, the questionnaire requested information on the maximum size of vehicle allowed in the area, the degree of urban access permitted, vehicle condition, hitching methods used, weight restrictions, truck routes (including traffic disruptions), accidents, damage to pavement and street furniture, geometrics for urban truck routes, signalization, terminals, and environmental impacts. In addition to seeking responses to questions posed, copies of appropriate documents were requested in cases where guidelines or policies (other than those of the national or provincial and state manuals) were available.

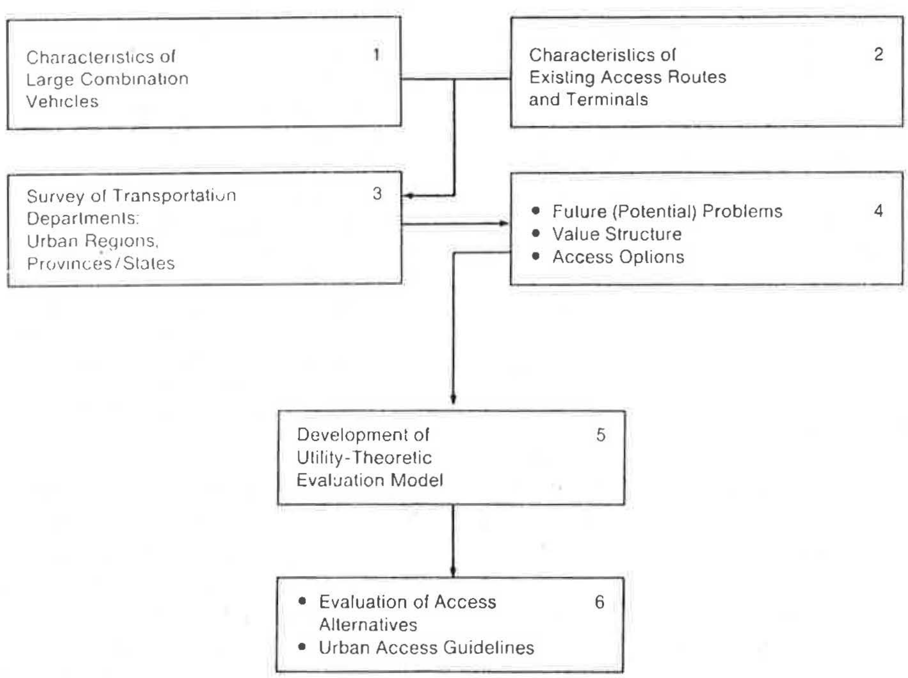

FIGURE 1 Methodological framework.

Questionnaires were sent to the chief executive officer of urbanized region transportation departments and provincial or state transportation departments, or both. The choice of urban regions was based on their location within a network of highways that is presently served, or could be served in the future, by large trucks. It was made clear in the questionnaire that "oversize" vehicle referred to vehicles greater than 90 ft (27.4 m) long and 8 ft (2.44 m) or greater width. The cover letter stated that through their cooperation, the research should result in a better appreciation of problems and opportunities for the accommodation of these vehicles on access routes and terminals.

Out of more than 200 questionnaires that were mailed out, a total of 58 responses were received (provinces/states 24, urban areas 34). The design of the questionnaire permitted responses on various modules by different divisions within a transportation department. A number of agencies, because of lack of information, did not respond to parts of the questionnaire. Also, because of the unusual length of the questionnaire (48 questions, 17 pages) and the detailed nature of the questions asked, the level of response from urban areas was rather low. Despite the modest response level on some modules of the questionnaire, this information base is the most comprehensive source of information on urban access factors known to the authors, including values expressed by transportation experts with urban and provincial or state government agencies in North America. Thus, the survey results noted as follows provide further insights into the urban access problem.

SURVEY RESULTS: PROBLEMS AND PROSPECTS

Factors for the design and evaluation of truck routes have been of interest to researchers and practitioners alike in the past. In the context of urban access for large combination trucks, their definition and relative importance is of special significance. Through a number of questions asked, a list of such variables has been compiled (Table 1). These consist of three types of factors: (a) truck transportation productivity improvement factors, (b) factors that define the cost of access routes (will probably be borne jointly by the urban and provincial/state governments), and (c) urban impacts on road users and residents.

Agencies surveyed were asked to show the importance of criteria on a scale of 1 (extremely unimportant) to 7 (extremely important). The results shown in Table 1 suggest that policy and planning experts have a balanced view of urban access issues. The top three criteria fall into the urban impact category (i.e., limiting large trucks to major commercial or industrial routes, safety, and traffic disruption).

Ranks 4 and 6 go to access route cost variables, and truck productivity factors receive Ranks 5 (access to terminal) and 11 (truck delays). It appears that providing access to terminals is accorded sufficient importance. Environmental impacts, because of their low levels, are not rated high compared with safety and convenience factors.

As for existing criteria for truck terminal location and planning, there do not appear to be many guidelines that have to be followed by common carriers except, of course, zoning regulations (Table 2). In general, terminals are not required to be within the defined distance of currently designated truck routes. This implies that part of existing urban access routes may be on roads that are not designed to handle even tractor semitrailer traffic adequately. Also, a very high percentage of transportation departments do not provide truck routes to any location requested by a terminal operator.

Existing terminals may have difficulty in accommodating future truck traffic requirements. Respondents suggest that in

TABLE 1 CRITERIA FOR THE EVALUATION OF LARGE TRUCK URBAN ACCESS ALTERNATIVES SURVEY RESULTS

Criteria	Rank	Rating (scale of 1 to 7)	Standard Deviation
Truck transportation productivity			
Provide access to terminal	5	5.14	1.46
Minimize truck delays	11	3.41	1.37
Access route cost			
Minimize pavement damage	4	5.30	1.43
Minimize cost of geometric improvements	6	4.70	1.29
Urban impact			
Avoid the use of local collectors (prevent trucks from entering residential areas)	1	6.52	0.73
Maximize safety	2	6.26	1.05
Minimize urban traffic disruption	3	5.48	1.44
Minimize noise	7	4.52	1.27
Minimize vibrations	8	4.18	1.47
Minimize air pollution	9	3.91	1.38
Minimize visual pollution	10	3.87	1.55

NOTE: Twenty-three agencies responded to this question.

TABLE 2 SELECTED SURVEY RESPONSES: TERMINALS

	Response	Percentage
Existing terminals		
Are terminals required to be within defined distance of currently designated truck route? (23 agencies responding)	Yes No	13 87
Are new truck routes provided to any location requested by a terminal operator? (18 agencies responding)	Yes No	17 83
Are terminals required to make provision for expansion? (14 agencies responding)	Yes No	7 93
Do you have regulations which prohibit queueing outside the terminal on the access road? (26 agencies responding)	Yes No	15 85
Are oversize vehicles allowed to park outside the terminal? (16 agencies responding)	Yes No	50 50
Are there any provisions of parking control regulations which specifically relate to oversize trucks? (26 agencies responding)	Yes No	23 77
Future terminals		
Will the location of terminals near main highways be an essential criterion in the near future? (17 agencies responding)	Yes No	53 47
Have you considered the "common carrier" Co-op terminal? (21 agencies responding)	Yes No	95 5
Do you intend to evaluate the possibility of establishing a "common carrier" Co-op terminal? (21 agencies responding)	Yes No	0 100

most urban areas, terminals are not required to make provision for expansion and there are no regulations that prohibit queueing outside the terminals on access roads. About one-half of responding agencies indicate that oversize, vehicles are allowed to park outside terminals. In fact, more than two-thirds of agencies stated that there are no provisions of parking control regulations that specifically relate to oversize trucks.

There are indications that the presence of large vehicles will influence future planning for terminals (Table 2). Over one-half of the respondents expect that the location of terminals near main highways will be an essential criterion of urban access. Comments received indicate that new terminals could be appropriately located in industrial parks in the vicinity of major highways. There is, however, little support for the common carrier "cooperative" terminal concept.

Survey responses on truck routes indicate that existing regulations are not strict enough for controlling the urban travel of large trucks (Table 3). Over one-half of the responding agencies indicate that truck routes are not restricted for use by certain specific sizes or gross weights of vehicles. Although truck routes are marked by proper signs, there are infractions of the designated truck-route system.

TABLE 3 SELECTED SURVEY RESPONSES: TRUCK ROUTES

	Response	Percentage
Existing practice		
Are truck routes in urban areas restricted for use by certain specific sizes or gross weights of vehicles? (28 agencies responding)	Yes No	43 57
How are truck routes marked through urban areas? By sign? (24 agencies responding)	Yes No	63 37
Are there any infractions of the designated truck route system? (25 agencies responding)	Yes Probably No	80 8 12
Future routes		
Have the urban truck routes in your area been reviewed for use by oversize vehicles? (27 agencies responding)	Yes No	59 41
Have or will any special geometric criteria be introduced for the design of urban truck routes in future? (18 agencies responding)	Yes No	33 67
Have or will any change be made to the signalization at intersections along truck routes to allow for oversize trucks to clear the intersection? (28 agencies responding)	Yes No	14 86

A majority of agencies have reviewed truck routes in their areas. Interestingly, a majority of respondents have not or will not introduce special geometric criteria for the design of urban truck routes. Also, a very high percentage (86 percent) of respondents indicate that urban areas have not or will not make changes to the signalization at intersections along truck routes to allow for oversize trucks to clear the intersection. This appears to indicate that access of oversize combination trucks at existing terminals located in a highly dispersed manner is not necessarily regarded as a viable solution to the urban access problem (Table 3).

Survey responses that fall into the urban impacts category are shown in Table 4. Eighty-nine percent of respondents have not modified or introduced any extra safety precautions on urban truck routes owing to the introduction of oversize vehicles.

TABLE 4 SELECTED SURVEY RESPONSES: URBAN IMPACTS

	Response	Percentage
Have you modified or introduced any extra safety precautions on urban truck routes because of the introduction of oversize trucks? (28 agencies responding)	Yes No	11 89
Do you consider that tractor trailer combinations significantly increase congestion on urban road network? (31 agencies responding)	Yes No	65 35
On the urban street network, are you experiencing damage which may be attributable directly to the use of increased (oversize) truck sizes? (22 agencies responding)	Yes No	41 59
Do you anticipate any increase in the rate of damage occurrence in 5 years time? (16 agencies responding)	Yes No Probably Unknown	31 37 13 19
Do you anticipate any increase in environmental pollution (noise, emissions, visual, other . . .)? (25 agencies responding)	Yes No	36 64
Do you have any regulations governing environmental pollution which were formulated or revised to apply to oversize trucks? (25 agencies responding)	Yes No	4 96

Sixty-five percent of the responding agencies expect that tractor-trailer combinations will significantly increase congestion on urban networks. A majority of respondents are not experiencing damage to pavements and road furniture attributable directly to oversize trucks. The reason stated for this observation is the low volume of large trucks presently using urban roads. However, a reasonably high proportion of agencies anticipate an increase in the rate of damage occurrence in the next 5 years (Table 4).

Sixty-four percent of respondents do not expect an increase in environmental pollution (i.e., noise, emissions, visual pollution, and so forth) attributable to large combination trucks. Almost all (96 percent) agencies indicate that they do not have any regulations governing environmental pollution that were formulated or revised to apply specifically to large trucks (Table 4).

Responding agencies prefer truck routes that loop outside a city with specific access points (see Table 5). Next in the order of preference is the type that loops within the urban area, and the hub and radial type of truck route (which generally accommodates heavy urban traffic volumes) was assigned the last rank. Respondents also indicate that urban transportation authorities consider large trucks, including combination vehicles, to be reasonably well maintained (Table 5).

ACCESS OPTIONS

Four options can be defined for providing large combination truck service to urban areas that are connected by major highway networks. The first option is to allow oversize trucks

TABLE 5 SELECTED SURVEY RESPONSES: IMPORTANCE OF CRITERIA

	Average Score (scale of 1 to 7)	Standard Deviation
Truck Routes[a]		
What type of truck route layout do you operate and favor for an urban area served predominantly by oversize trucks?		
Loop outside city with specific access points	6.15	0.99
Loop within city	3.95	2.22
Hub and radial	2.90	1.85
Urban Impacts[b]		
From your experience are the vehicles well maintained and in good condition?		
Trucks (straight)	4.81	0.68
Tractors	4.90	0.70
Trailers	4.86	0.65

[a]13 agencies responding.
[b]21 agencies responding.

to use the shortest route available to reach terminals. In such a scenario, most terminals requiring access are those that are already in existence. Such terminals are not necessarily clustered in a limited number of locations very close to highway interchanges. This option, in general, would follow the current practice of reaching truck terminals.

A second option would require that terminals be located within a short distance (e.g., up to 5 km) from major interchange points. The use of distance as the only criterion may not permit access to a reasonable proportion of existing terminals. Also, there is hardly any assurance that appropriate sites could be found in the vicinity of interchanges for the development of new terminals.

A third option is to locate terminals within industrial parks that are situated along major highways. In most instances, these sites are within 5 to 8 km of major interchanges and are generally accessible by major roads. Because of their highly commercial and outlying nature, any access road improvements can be implemented without unreasonable cost. However, this option would require the establishment of design and operational standards that are best suited for long combination trucks.

Finally, a fourth option for providing urban access to large combination trucks is that of staging areas on or adjacent to the intercity network's right-of-way (i.e., major interchanges). However, such sites, although difficult to find within the urban part of the right-of-way, are meant only as break-up points and are not intended to serve as terminals. This option is the most restrictive in terms of serving urban areas but avoids the use of combination vehicles on urban roads.

In this paper, these access alternatives (i.e., policy options) are assessed by using a utility-theoretic evaluation model described as follows. Results of the survey of transportation departments are also used in the example application.

UTILITY-THEORETIC EVALUATION MODEL

Urban access policy decisions require trade-offs between the degree of urban access offered to long combination trucks and the extent of urban impacts, including the cost of building or modifying major urban roads. The higher the degree of access, the lower the motor carriers' cost of serving an urban area, and therefore the higher the truck transportation productivity. On the other hand, the higher the degree of urban access, the greater the extent of urban impacts, including higher urban road costs.

A utility-theoretic model conceptualized by Khan in an earlier paper can be further developed here and applied to the urban access problem (*9*). A previous application of utility theory to a simpler truck route choice problem was carried out as a graduate research thesis at Carleton University (*10*).

In Figure 2, the urban community's indifference between the value of large truck access and its impacts is represented by curve *I*. For given resources (i.e., monetary and other), technical trade-offs that are possible between urban access provided and resulting urban impacts are represented by lines T_1, T_2, . . ., and so on. A specific *T* line defines a given magnitude of resources. Point *A*, which is the point of tangency between a given *I* curve and T_1 line is the optimal degree of access for T_1 level of resources. Of course, a higher magnitude of resource expenditure, such as shown by T_2, would enable a higher optimal level of access. On the other hand, if urban access higher than *A* level is allowed and resource expenditures are defined by T_1, the extra urban impacts are more than enough to offset the extra welfare from increased access. In such a case, the urban area moves to a lower indifference curve.

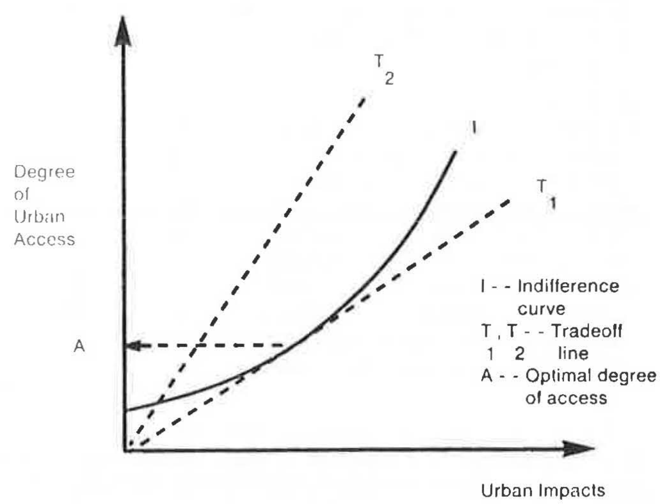

FIGURE 2 Urban access versus impacts.

From an urban community perspective, low-cost trucking services provide benefits to all the production and consumption sectors and up to a certain degree of urban access, social benefits outweigh social costs. Also, conceptually, the optimal degree of urban access is at a location where net benefits are the highest (Figure 3). The social choice of the oversize truck urban access policy is conceptualized in Figure 4. On the

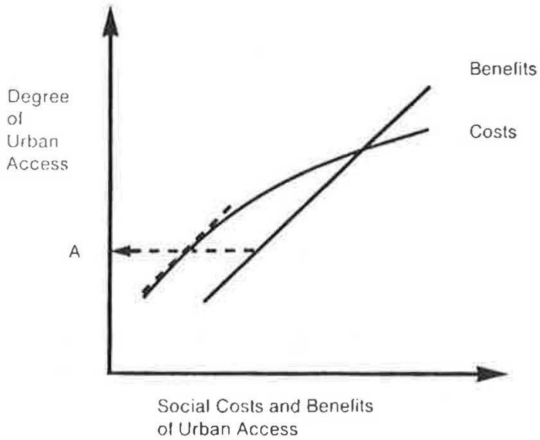

FIGURE 3 Costs and benefits of urban access.

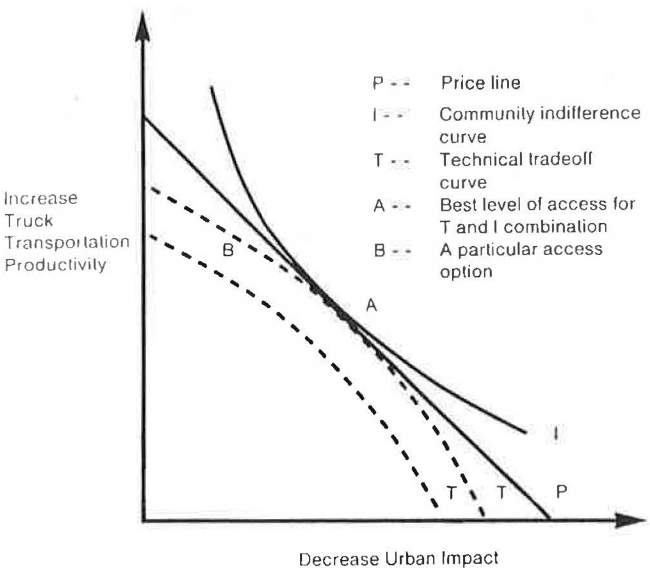

FIGURE 4 Social choice of urban access.

assumption that equity or distributional aspects can be taken into account, as described later in this paper, the access choice problem is based on the identification of the best possible combination of truck transportation productivity and urban impact outputs for a given level of resource inputs. As shown in Figure 4, this is the urban access level *A* that is the point at which the technical trade-off curve, *T*, is tangent to the community indifference curve, *I*.

Community value structure and the extent of physical and monetary impacts associated with the various levels of access determine the optimality point. For example, in environmentally sensitive congested urban areas, optimal degree of urban access may turn out to be the minimal level of access provided in the form of staging areas. On the other hand, for relatively newer urban developments with well-positioned industrial areas and relatively unconstrained urban road rights-of-way, the best option might turn out to be access to terminals located within industrial parks. In order to assist transportation planners and policy analysts, the utility-theoretic methodology, described later in this paper, can be used to establish the best access level that would reflect local conditions as well as value structure.

In considering urban access options, the question of the incidence of costs and benefits cannot be ignored. Although traditional approaches to urban transportation policy decisions have tended to emphasize economic efficiency and productivity and ignore the distributional aspects of urban impacts, there is, however, the increasing sensitivity to the equity question at this time. Despite the recognition of the goal of distributional efficiency, available methodology cannot accommodate the complexity of the access problem for a various reasons. First, for a number of urban impacts, objective measures do not exist. Second, market prices are not available for a number of impacts. Third, direct aggregation of quantifiable costs and benefits in any form without weighting the costs and benefits for the impact groups would be inappropriate. Clearly, there is a need for an innovative approach to help decision makers decide on the degree of urban access to be provided to oversize trucks.

It is assumed that urban access alternatives are to be evaluated by using criteria such as those listed in Table 1. These are designated as $cr_1, cr_2, \ldots, cr_g, \ldots, cr_q$. Two conflicting criteria are shown in Figure 5. The outputs (representing various levels of criteria attainment) are aggregated on an urban network basis and weighted for the relevant impact groups. The community indifference curves (I_1, I_2, I_3), assumed linear in this model for operational reasons, express the relative importance of the criteria—defined by weights, w_g. All possible alternatives, $a_1, a_2, \ldots, a_m$, are defined by the technical trade-off curves shown as T_1, T_2, and T_3. A given trade-off (constant resource) curve, say T_1, would represent a subset of all possible alternatives. The outputs and trade-off curves can be expressed in relative value units (e.g., utils or dollars), as described in the following paragraphs.

In this formulation of the utility-theoretic model, it is assumed that uncertainties do not exist in the estimation of access costs and truck transportation as well as urban impacts. Access

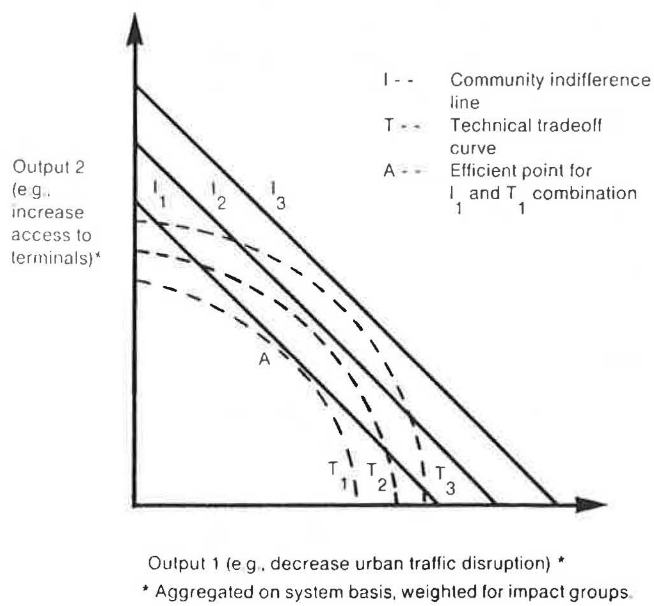

FIGURE 5 Combination of economic and distributional efficiency criteria in access policy evaluation.

alternatives are defined by their outcome states, for any affected component of the urban community, including interest groups (e.g., commuters, other motorists, urban residents, and so on). The outcome states are defined by combining the various levels of criteria attainment (through the use of "and" ^ "not" ~ symbols):

$$o_1 = \mathrm{cr}_{11} \wedge \mathrm{cr}_{21} \wedge \ldots \wedge \sim (\mathrm{cr}_{12} \wedge \mathrm{cr}_{22} \wedge \ldots) \wedge \sim (\ldots.)$$

$$o_2 = \ldots$$

where

$$\mathrm{cr}_{11} = y_1\, \mathrm{cr}_{11}^1 + y_2\, \mathrm{cr}_{11}^2 + \ldots + y_x\, \mathrm{cr}_{11}^x;$$

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cr_{gh} = $y_1\, \mathrm{cr}_{gh}^1 + y_2\, \mathrm{cr}_{gh}^2 + \ldots + y_x\, \mathrm{cr}_{gh}^x$;
cr_{gh}^x = the hth level of impact of criterion g on group x (e.g., travel delay to urban motorist group x);
y_x = a weight, reflecting the importance of the impact group x with respect to the criterion g, and can be determined from community's preference expressed as ranks or weights; and
cr_{gh} = the hth level of criterion g, weighted for all impact groups.

It should be noted that urban areas may not wish to weigh impacts according to impact groups. In such a case, only one value of cr_{gh} would be applicable.

The worth or value of an urban access alternative a_m can be found by determining the value of its outcome state o_m to the society. This involves the estimation of the weighted impacts (the criteria attainment levels) for all the groups. Two steps are required for obtaining the final answer. In the first step, the state of the system is to be found that is likely to occur as a result of the implementation of the access alternative. All outputs that correspond to the criteria are estimated through a variety of technical means that range from sophisticated models (e.g., traffic interruption, noise pollution) to subjective assessments.

Following the estimation of outcome or impact state for access alternatives, the second basic step is taken in the form of evaluation of the resultant states. The value of outcome states in relative value units is found by using value functions and applying criteria weights:

$$U(a_m) = U(o_m) = w_1 u_1 (\mathrm{cr}_{1h}) + w_2 u_2 (\mathrm{cr}_{2h}) + \ldots + w_g u_g (\mathrm{cr}_{gh})$$

where

u_g = a numerical function on the gth criterion;
cr_{gh} = the hth level of criterion g;
$u_g(\mathrm{cr}_{gh})$ = the value of the hth level of cr_g measured by numerical function u_g, in units of measurement that may be different from the original units of cr_g; and
w_g = criteria weight determined from the community or the decision maker's preferences.

Value functions are used for the transformation of criteria-attainment estimates measured in their original but diverse scales (including subjective scales such as 1 to 7) to relative values or utils measured on a 0 to 1 scale. Value functions may be of the following form:

$$u_g(\mathrm{cr}_{gh}) = s_g v_g(\mathrm{cr}_{gh}) + b_g \qquad \text{for all } \mathrm{cr}_g,\ g = 1, 2, \ldots, q$$

where $v_g(\mathrm{cr}_{gh})$ is the original value of cr_{gh}, and s_g and b_g are constants.

The $U(o_m)$'s can be expressed in units of any criterion (e.g., dollars) by transformation. For example, the following transformation is allowed:

$$U(o_m) \text{ in units of } \mathrm{cr}_g = 1/s_g\, w_g\, [U(o_m) \text{ in relative value units}] - b_g/s_g$$

The weights y_x and w_g can be obtained from an expression of values by representatives of the urban community. The mechanism that can be used is that of expressing preferences through rating, ranking, or other methods by elected officials, their policy experts, and representatives of special interests. It should be noted that criteria weights shown in Table 1 were obtained from transportation experts and do not represent the views of elected officials or of special interest groups.

Through value functions and criteria weights, the urban community's valuation of each outcome state can therefore be expressed as a single quantity: $U(o_m)$. These establish the ranking of states according to their desirability. In Figure 5, Point A represents the most cost-effective alternative for the I and T combination.

EVALUATION OF URBAN ACCESS ALTERNATIVES: MODEL APPLICATION

Four urban access alternatives defined earlier are evaluated here through the application of the utility-theoretic model. Eleven criteria as well as their relative weights shown in Table 1 are used for establishing the relative desirability of access alternatives. In this example application of the model, the access alternatives are not being evaluated for any specific urban area. Instead, on the basis of the knowledge of average conditions in North America and the findings of the survey reported earlier, criteria achievement levels are estimated and weighted by using weights obtained from the survey (Table 6). Although there is a substantial degree of realism in the example application presented here, the main objective is to illustrate how urban areas could use the methodology advanced here to evaluate their urban access policies.

The criterion of providing access to terminals is completely met by Alternatives 1 and 3 and the policy of limiting urban access to staging areas (Alternative 4) is in the lowest attainment level. Alternative 2 would allow about 60 percent of the terminals to be reached by oversize vehicles. As for the criterion of minimizing truck delays and associated costs, the use of staging areas would be the least effective option and locating terminals in industrial parks would be the most effective.

From the trucking industry perspective, access to terminals is important for productivity reasons. Less-than-truckload type

TABLE 6 EVALUATION OF URBAN ACCESS ALTERNATIVES CRITERION ACHIEVEMENT LEVEL u_g (cr_{gh})/ WEIGHTED VALUE w_g u_g (cr_{gh})

Criteria	Alternative 1 Shortest Route	Alternative 2 Terminals Within 5 km Distance	Alternative 3 Terminals Within Industrial Parks	Alternative 4 Staging Areas
cr1 Provide access to terminal	1.0/5.14	0.6/3.08	1.0/5.14	0.0/0.0
cr2 Minimize truck delays	0.85/2.9	0.8/2.73	1.0/3.41	0.0/0.0
cr3 Minimize pavement damage	0.7/3.71	0.75/3.98	0.8/4.24	1.0/5.3
cr4 Minimize geometric improvements	0.7/3.29	0.7/3.29	0.85/4.0	1.0/4.7
cr5 Avoid local collectors	0.8/5.22	0.9/5.87	0.95/6.19	1.0/6.52
cr6 Maximize safety	0.75/4.7	0.8/5.01	0.9/5.63	1.0/6.26
cr7 Minimize urban traffic disruption	0.75/4.11	0.8/4.38	0.85/4.66	1.0/5.48
cr8 Minimize noise	0.65/2.94	0.7/3.16	0.75/3.39	1.0/4.52
cr9 Minimize vibrations	0.65/2.72	0.7/2.93	0.75/3.14	1.0/4.18
cr10 Minimize air pollution	0.65/2.54	0.7/2.74	0.75/2.93	1.0/3.91
cr11 Minimize visual pollution	0.65/2.52	0.7/2.71	0.75/2.9	1.0/3.87
Utility of alternative $U(a_m)$	39.79	39.88	45.63	44.74

of service, which could potentially use triple trailers, is a heavy user of terminals. For truckload type of service, major loading or unloading points are generally located in industrial parks. In newer developments, most manufacturing facilities, warehouses, and other generators of large loads (that would be carried in large trailers) are located in industrial areas within 3 to 5 mi (5 to 8 km) of major highways. It is hardly surprising that major new truck terminals are increasingly being located within industrial parks.

In incremental terms, pavement damage would not be an issue if oversize trucks were not permitted beyond staging areas. Properly designed roads providing access to industrial parks or terminals in the vicinity of major highways would be more effective in minimizing pavement effects than other routes. As for the minimization of the cost of geometric improvements, the worst performer is the option of allowing access on the shortest route basis. The alternative of using staging areas involves no geometric changes to truck routes.

Vehicle turning performance is a critical factor for establishing the adequacy of geometric design features for existing or new roads. The turning space required increases with an increase in trailer length or number of trailers. In general, longer vehicles with fewer articulation points have higher offtracking characteristics (*4*). Offtracking is more serious for turnpike doubles than for triples (*6*). At urban intersections with restrictive rights-of-way, rocky mountain doubles and turnpike doubles would have to encroach on opposing traffic lanes to make the right-hand turn (*4*). In the case of intersecting roadways with two lanes each (e.g., minor arterials, local collectors), longer combination trucks would not be able to make left turns without using the space of opposing traffic (*4, 6*).

Although in theory local collectors are not included in truck routes, there are instances where large trucks may have to use segments of such roads to reach terminals. In this respect, the alternative of using the shortest route would involve the highest incidence of the use of minor arterial and local collectors.

In relative terms, safety problems would be the most pronounced should a policy of allowing terminal access on the shortest route basis be adopted. Safety problems could arise because of vehicle offtracking, braking time, trailer sway (in the case of triple trailers), blocking the view of motorists, and the difficulty oversize trucks have in making emergency maneuvers. In cases where oversize vehicles may have to run over curbs in unexpected maneuvers, there would be a problem of instability.

Traffic disruption would not be an issue if the option of staging areas is selected. On the other hand, the highest level of traffic disruption would be encountered in the case of using the shortest route option. Large combination trucks take more time and space to turn and therefore would impede traffic.

As for environmental impacts, the best option is, of course, that of limiting urban access to staging areas only. The order of desirability of other options in minimizing environmental impacts is Alternative 3 (terminals within industrial parks), Alternative 2 (terminals within 5-km distance), and—the least attractive alternative—allowing access on the shortest route basis (i.e., Alternative 1).

Results shown in Table 6 suggest that the alternative of providing access to terminals within industrial parks has the highest utility and the alternative of limiting access to staging areas is almost equally attractive. On the other hand, the policy of using the shortest route to existing terminals is the least attractive option. The policy of limiting access within a 5-km distance without regard to the type of areas or the type of roads available is marginally better than the shortest route option.

CONCLUSIONS

Owing to the substantial potential urban impacts of oversize trucks, it is essential that relevant sociotechnical factors and the welfare of interest groups be included in access policy decisions.

Transportation departments in North America, who responded to the questionnaire survey, have expressed a balanced view of urban access issues by recognizing the importance of urban impacts as well as terminal access. However, in general, urban impact factors are accorded higher importance than providing access to terminals.

An outstanding need for methodology for making trade-offs between the benefits of providing urban access to large combination trucks and urban impacts is met through the utility-theoretic evaluation model. This tool is the most appropriate mechanism for treating the urban access criteria and enabling the quantification and use of community values.

Major guidelines for providing urban access are noted as follows:

- Terminals in outlying industrial parks should be made accessible. Such industrial parks are generally situated on outer loops or rings, within a 3- to 5-mi (5- to 8-km) distance from highway interchanges. With properly designed access facilities and terminals located in industrial parks, the 3-mi (5-km) distance criteria used by a number of jurisdictions could be relaxed.
- Access roads to terminals located within industrial parks should be developed with geometric standards that are best suited for oversize trucks.
- Providing access to dispersed urban truck terminals through existing truck routes cannot be regarded as a feasible solution. Most existing urban routes cannot handle oversize trucks without safety and traffic disruption problems.

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REFERENCES

1. A. M. Khan. Canadian Highway Transportation: A Strategic Research and Development Program. A.K. Socio-Technical Consultants (Ottawa) Incorporated, prepared for Transport Canada, Ottawa TP6 278E, Canada, March 1985.
2. M. F. Clark, J. R. Pearson, and J. B. L. Robinson. Heavy Vehicle Weights and Dimensions in Canada: Research, Rationalization and Regulation. Paper Presented at the 65th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 1986.
3. A. M. Clayton and F. P. Nix. Effects of Weight and Dimension Regulations: Evidence From Canada. In *Transportation Research Record 1061*, TRB, National Research Council, Washington, D.C., 1986, pp. 42–49.
4. *The Feasibility of a Nationwide Network for Longer Combination Vehicles*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., June 1985.
5. J. P. Eicher, T. E. Klimek, and S. G. Strickland. National Network for Trucks: Development, Performance, and Outlook. In *Transportation Research Record 1052*, TRB, National Research Council, Washington, D.C., 1986, pp. 2–5.
6. J. R. Billing. *Summary of Tests of Baseline Vehicle Performance*. Ontario Ministry of Transportation and Communications, CV-86-12, Downsview, Ontario, Canada, June 1986.
7. O. Carsten. Safety Implications of Truck Configuration. In *Transportation Research Record 1111*, TRB, National Research Council, Washington, D.C., Jan. 1987, pp. 17–26.
8. *Special Report 211: Twin Trailer Trucks*. TRB, National Research Council, Washington, D.C., 1986.
9. A. M. Khan. Transportation Policy Assessment: Costs and Benefits of Environmental Quality. *High Speed Ground Transportation Journal*, Vol. 7, No. 1, 1973, pp. 101–127.
10. M. A. Gravel. A Truck Route System Evaluation and Selection for the City of Hull. M.Eng. thesis, Carleton University, Ottawa, Canada, 1980.

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