look for a ratio of 3 to 1 or better in a successful application.

The UDAG program works because it is not concerned with normal budgeting and funding. It is a small pool of federal money available to anyone who wants to go out, do some leg work, get some commitments, and come back with a suitable application. No other program in the field of urban transportation is comparable to it.

Operating assistance parallels the block grant concept: a sum of money is given with no strings attached except to account for how it is spent. Capital grants are categorical; i.e., a host of conditions must be met, including alternatives analyses, Buy America, and E&H accessibility. To date, no grant is tied specifically to leverage.

Adding leverage to the capital grants program as another categorical condition is not proposed here. A grant with a small portion having leverage as its main criterion and available only to communities who could demonstrate its efficient application is a possible approach.

An earlier section of this paper proposed a federal loan program that might provide loans directly as well as loan guarantees. This, coupled with the Economic Recovery Tax Act of 1981, might create a strong incentive for local commitment of tax revenues. The biggest problem in lease-back sales is finance.

Because the government has been partly responsible for the rise in operating deficits, it could provide a financial incentive to reduce deficits. This might be matching actual cost savings by local transit authorities that reduce deficits and do not reduce services. The recipient authority would agree to use the federal incentive payments to improve productivity by providing more services and/or improving its capital plant.

These incentive finance programs have the potential to leverage local commitments. The loan program would provide the greatest amount of leverage, because the only costs to the government are administrative and the time cost of money. The incentive plan to reduce deficits could be applied only until a local commitment is made to fill the gap left by ending operating assistance.

CONCLUSION

The federal government is partly responsible for the current state of transit and consequently has the responsibility to help find solutions, especially if it plans to cancel its previous programs that worked toward these solutions.

A concept has been proposed in which the federal government acts as the lever to gain local funding commitment, to induce investments by industry to develop better products, and to encourage operating cost savings. Federal involvement is based on a simple qualification: The benefits to the nation must be greater than the investment.

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Feasibility Criteria for Light Rail Transit

LAWRENCE N. DALLAM and NATALIO DIAZ, Metropolitan Council of the Twin Cities Area, and DAVID RUBIN, COMSIS Corporation

The evaluation of rail technology as a potential component of regional transit systems has been the subject of extensive studies throughout the country in the past decade. Particular interest has developed in the last few years with respect to light rail transit. In 1980, the Minnesota Legislature directed The Metropolitan Council, the regional planning agency, to conduct a feasibility study on the deployment of LRT in the Twin Cities. For the study, feasibility was defined as "the ability of an LRT line to achieve regional transportation goals in comparison with other transportation alternatives." This paper describes the feasibility criteria developed in the Twin Cities to evaluate a proposed project. A dichotomy was established between qualifying and nonqualifying criteria. The minimum are those conditions that would have to be met to make a project feasible for further evaluation.

Light rail transit is being employed or proposed in several North American cities as a partial solution to urban transportation problems. It is regarded as a compromise between continued dependence on buses and larger investments in heavy rail. LRT also requires a greater capital investment than buses and an operational commitment for at least 20 to 30 years to justify the investment in right-of-way, infrastructure, and vehicles. This long-term commitment challenges the decision process and creates the need for a thorough evaluation, including the development of feasibility criteria.

Rail technology as a potential component of the Twin Cities regional transit system was the subject of extensive and controversial studies during the early 1970s. The result was the adoption in 1976 of an all-bus regional transit plan that explicitly excluded "fixed guideway for the exclusive use of transit" before 1990. Since 1976, however, several factors—rapidly rising bus operating costs, increasing use of public transit, and the possible future scarcity of petroleum products—have made high-capacity, less labor-intensive modes such as LRT increasingly attractive.

In 1980 the Minnesota Legislature directed the regional planning agency, the Metropolitan Council, to conduct a feasibility study on the use of light rail transit in the Twin Cities Metropolitan Area. This mandate required the Council to determine the conditions necessary for LRT to be feasible, and thus emerged the need to define feasibility and to develop feasibility criteria.

Generally, feasibility refers to whether an action under consideration is "desirable, achievable, suitable, advisable, appropriate, or political."[1] Based on this definition, feasibility could be determined only by considering alternatives other than the one under study, so a series of alternatives to LRT was developed. It was also clear that the feasibility of any proposed public investment should be measured against the goals and policies established by the community to be served. Therefore, the feasibility of installing an LRT line in the Twin Cities was defined for the study as "the ability of an LRT line to achieve regional transportation goals in comparison with other transportation alternatives."[1]

The following regional transportation goals were considered:

- To provide metropolitan residents with good accessibility to regional and subregional opportunities;
- To provide residents of the Urban Service Area[2] with efficient, convenient, and attractive choices of transportation to both regional and subregional opportunities;
- To utilize transportation to strengthen the two downtowns or Metro Centers of Minneapolis and St. Paul;
- To coordinate metropolitan transportation services and investments with other metropolitan services and investments in order to determine priorities on the basis of overall metropolitan needs and the ability of the area to support these services and investments over time; and
- To provide transportation facilities and services that produce positive impacts on the social, economic, and physical environment and conserve the supply of metropolitan energy sources.

Feasibility criteria are needed to evaluate alternatives. The alternatives to LRT, such as bus improvements, trolley buses, and heavy rail, all entail trade-offs between capital costs, operating efficiency, environmental impacts, and land development effects. Criteria are required to compare these alternatives and determine which one has the best combination of characteristics. The criteria should either explicitly state the necessary result or define the values that are applied in the decision. Values that can be quantified—that provide a numerical estimate for comparison or qualification—are easy to define when assessing feasibility; for instance: "LRT is feasible if its operating costs are less than those of the alternative" or "LRT is feasible if it can carry more passengers in the peak hour than another alternative." Those that do not lend themselves to quantification can also be used to determine feasibility, but they require the willingness to apply judgment.

Some criteria are critical to final decisions concerning actual implementation, and failure to meet them can eliminate an alternative from consideration. Excessive cost, unacceptable environmental impact, residential dislocation, or lack of citizen support are sufficient reasons for a negative determination. These vetoing criteria must be based on local goals and values.

QUALIFYING AND NONQUALIFYING CRITERIA

As feasibility criteria were developed for the Twin Cities, it became evident that a distinction must be made between two different types. While certain conditions had to be met to make an alternative feasible for further evaluation, other criteria would not be sufficient to render it infeasible. From this dichotomy, the concept of qualifying and nonqualifying criteria surfaced, and two sets of feasibility criteria for evaluation of the proposed LRT lines were developed.

Qualifying criteria are previously established regional goals that must be met. Failure to meet any of them would result in an LRT line that would not be eligible for further evaluation. Nonqualifying criteria, on the other hand, may not be met in their entirety; they serve for comparison, evaluation, and weighting purposes and as a means of identifying problems.

The disqualifying flaw in an alternative, as used here, is one inherent in the alternative that cannot be remedied. For example, an LRT line that disrupts a neighborhood and creates a barrier would not be judged infeasible if minor alignment shifts could alleviate the problem. But inadequate patronage or excessive cost to carry the line across a river could be reasons to determine infeasibility.

Nonqualifying criteria are intended primarily to rank proposed alternatives and identify potential problems associated with their implementation. In other words, these in time should establish a hierarchy among alternatives that make it possible to select one of them for implementation planning.

Both qualifying and nonqualifying criteria can be grouped into the following categories:

- Physical impact criteria,
- Transportation criteria, and
- Economic criteria.

Physical Impact Criteria

The first category relates to three physical impacts: land use, energy, and the environment. These impacts are based on an evaluation of the hypothetical construction and operation of a specific LRT line and its alternatives. Most of these impacts cannot be evaluated without decisions on specific alignment, operating characteristics, and patronage.

Land use is the most complex factor to evaluate because much of the development-related impact is projected and hypothetical. Some criteria, however, emerge as a basis for qualifying.

Neighborhood disruption is one major adverse impact of transportation improvements. Neighborhoods that consider minibus traffic disruptive would find an LRT line, which is larger and more visible (wires, tracks, and shelters), totally unacceptable. Limiting LRT alignments to major streets and rail rights-of-way eliminates most problems, but there may be situations that require cutting through a neighborhood to circumvent major barriers (lakes, hills, etc.). In such cases (which did not exist in the

Twin Cities), criteria are needed to decide the issue. Such a criterion might be "the LRT line should not use, as right-of-way, local residential streets, as defined in the comprehensive plan for the community."

Similar criteria could be developed for such other adverse land use impacts as housing dislocation, disruptive use of park land, proximity to elementary schools, etc. In most such situations, the criteria will result in the proposed LRT line's realignment rather than its elimination, since these land uses usually can be avoided in laying out an LRT line.

There are, conversely, positive land use impacts that may become necessary conditions for building a line. For instance, in the Twin Cities, the major qualifying land use criterion was "the LRT line should serve at least one of the two Metro Centers."[2] This was based on the following considerations: The two centers are the primary foci of the entire transit system, LRT is the most accessible transit mode being considered, and regional goals require that such accessibility improvements focus on the two downtowns, not detract from them. On the other hand, to strengthen the two downtowns through transportation strategies is also a major regional goal, and because LRT is a relatively capital-intensive alternative, its cost-effectiveness can be achieved only along alignments with high ridership demands. It was believed that only service linked to a downtown area could generate these high levels.

Other positive land use impacts were not considered to be as critical and were evaluated using nonqualifying criteria, including service to secondary land uses. One such criterion states, "The LRT should link major activity centers and other large traffic generators to the Metro Center."[2] The purpose of LRT in these cases was to provide access between major population centers and the Metro Centers and use the other major centers as foci for local transit service that would both feed the LRT and serve the centers.

A criterion that caused considerable discussion was conformance of the LRT alignment to local and metropolitan development plans. The basis for concern was the circular, iterative nature of the planning process; neither LRT planning nor land development planning can be done in a vacuum. The resulting nonqualifying criterion states: "The LRT line and local metropolitan plans for development and redevelopment should be mutually supportive."[2]

In essence, this criterion indicates that a proposed LRT line should be viewed negatively if it conflicts with local or metropolitan planning. Conversely, changes in a community's land use planning and zoning should be made when necessary to obtain maximum benefits from the proposed LRT line.

Today, energy consumption is a major factor when developing evaluation criteria. In LRT analysis, however, energy considerations can be confused and controversial. LRT would not necessarily save energy, but it most likly would save petroleum, because it is powered by electrical energy, which is often generated by nonpetroleum fuel sources. Feasibility criteria for energy consumption, therefore, must consider the magnitude, source, and location of energy generation.

Analysis of various area corridors showed that LRT energy consumption, in total Btu or K-Cals, approached and sometimes exceeded the energy consumption of nonrail alternatives, particularly when all energy resources, including feeder buses, resource production, and resource transportation (coal from mine to generator, oil from well to refinery, etc.) were included.[3] LRT's petroleum consumption, however, was less in every case than that of its alternative. One qualifying and one nonqualifying criterion emerged from energy analysis conducted in the Twin Cities. The qualifying criterion states: "The LRT line must conserve petroleum." In other words, the net result of constructing and operating an LRT line, adapting the bus service, and providing auto access to the line should be to reduce the consumption of petroleum fuel. The nonqualifying criterion considered all types of energy resources by stating: "The LRT line should conserve energy."

The environmental image of LRT is generally positive, and developing feasibility criteria for this purpose was relatively simple. LRT is quiet, clean, and does not usually need large structures. It does, however, require wires, tracks, shelters, and occasional bridges or underpasses, and it generates a different kind of noise.

Air quality impact evaluation is more complex because of the location of the power generator. Non-LRT alternatives usually pollute the air in the transportation corridors they serve, but these corridors are usually located in high-density urban areas with other pollution sources. LRT causes pollution at the power generator, but it may be located far from the urban area. These distinctions, like that between petroleum and nonpetroleum energy sources, must be considered when developing criteria.

None of the environmental criteria were stipulated as qualifying, on the assumption that the nonenvironmental impact of LRT would render it infeasible. Nonqualifying criteria included the following:

- The noise impacts of the LRT line should meet applicable state and federal standards.
- The LRT's physical facilities should be visually integrated with the environment.

Transportation Criteria

Transportation-related criteria are primarily intended to address accessibility and ridership considerations and to coordinate and integrate transportation modes.

In terms of accessibility, a qualifying criterion developed in the Twin Cities study stated, "An LRT line must meet the transit accessibility criteria, as defined in the Metropolitan Development Guide, for the corridor it serves." This refers to the following travel time policies contained in the regional transportation plan: "The public and multi-passenger transit system should provide a travel time of no more than 45 minutes in either peak or off-peak periods from any part of the Urban Service Area to one or the other of the Metro Centers for 90 percent of the residents of the Urban Service Area. The Transportation system (both transit and highway) should provide a travel time of no more than 30 minutes in off-peak periods from any part of a subregion to any other part of the subregion for 90 percent of the residents in the subregion."

Another criterion also emphasizes the importance of improving accessibility to the Metro Centers, as previously discussed under physical impact criteria.

The potential ridership of a proposed LRT line is also considered, although only nonqualifying criteria were developed for this factor. One states: "The LRT line should meet peak ridership demands."

The proposed line must be able to accommodate predicted demands, which may be difficult in some situations. For example, an LRT train's length can be limited by block length and storage capacity of downtown streets and by stop space and design at major traffic generators. If several LRT lines use the same streets, the street capacity may not be adequate for peak loads. Since LRT vehicles usually cannot pass one another, this could cause severe congestion on the system.

A second nonqualifying criterion related to ridership states: "An LRT line should increase overall transit usage in the region over the existing system."

In order to justify the initial capital investment, an LRT line should be more attractive to the rider than an existing transit service; i.e., an LRT line must have a shorter travel time than the bus route it replaces in order to attract more riders.

The need to coordinate and integrate a proposed LRT line with other transportation modes was also included in several nonqualifying criteria developed in the Twin Cities study. One states: "The LRT line should be integrated with the existing transportation system without serious disruption or degradation."

The Metro Centers, in particular, already have numerous transportation activities—pedestrian, automobile, bus, taxi, goods movement, and emergency service—that occur simultaneously in a limited area. The LRT line should be planned and designed to be compatible with these activities. Also, many LRT lines operate in the center of streets, at curbside, or on exclusive rights-of-way with at-grade crossings. These locations can interfere with existing traffic flow or with parking, especially when the LRT right-of-way was formerly a vehicular right-of-way. These dislocations can be mitigated by providing off-street parking, creating turning lanes at intersections, and improving signals. It is important to design a safe facility that does not create severe disruptions to other traffic.

Metro Centers in both the Twin Cities are well served by skyway systems that would permit pedestrian movements to and from the LRT line in a climate-controlled environment. However, to provide access to the skyway system at only one point would create delays and cause pedestrian congestion at that stop. Therefore, multiple access points are an important design feature, as specified: "The LRT line should serve multiple boarding points within the Metro Center to distribute passenger movements."

Many existing bus routes to the metropolitan centers would be rerouted to feed the LRT line. This system reorientation should be accomplished to minimize the overall travel time and provide riders as much convenience as possible, as stated: "The LRT line should be efficiently integrated with the existing transit system."

Economic Criteria

LRT will likely cost more to build than most non-LRT alternatives except heavy rail and other fully grade-separated systems. An operating cost advantage that could make building one or more LRT lines worthwile is the lower labor costs than for buses, because LRT can carry more people with fewer operators and complete more trips in less time. A proposed LRT line's cost-effectiveness should be determined by its capability to reach a break-even point in terms of total investment (capital, operating, and maintenance costs) compared to that of an alternative. Densities, peaking characteristics, and levels of service must be appropriate if a proposed LRT line is to be able to save enough to justify its larger capital expense.

Determining if LRT justifies its cost requires an economic analysis that includes a careful examination of all the assumptions used to calculate patronage and capital and operating costs, as well as interest rates, fares, subsidies, and cost allocation, including the following:

- Capital expenditures;
- Life of capital equipment;
- Prevailing interest rates;
- Sources of capital funds;
- Costs of operation (current and future) based on energy cost assumptions and labor cost assumptions;
- Fare structure and collection techniques; and
- Changes over time in patronage, equipment needs, and capital and/or or operating costs.

To calculate cost-effectiveness, conservative assumptions should generally be made concerning interest rates, labor costs, etc., although the combined assumptions should remain within reason.

An important objective of the analysis is to determine how long it will take for the annualized capital costs and operating costs to break even. When this break-even point is earlier than the predicted life of the capital equipment, the investment is justified. This point can be calculated at various inflation rates to determine LRT's feasibility as a function of a specific rate. This is particularly important when inflationary trends are a major factor in the overall economic picture. In the Twin Cities LRT Feasibility Study, inflation rates of 6, 8, 10, and 12 percent were used. The break-even year was calculated to range from 15 years after construction on the best corridor, assuming high inflation rates, to 51 years after construction on the least viable alternative at low inflation rates. This evaluation used only quantifiable dollar values and did not include intangible benefits, indirect costs and benefits, or secondary benefits. Such impacts might change the analysis, but the primary calculations provided enough data for a go or no-go decision on alternative corridors.

Criteria developed from this analysis reflect the concept that LRT should have operating benefits and that they should be related to its annualized capital costs. The qualifying criterion states: "The annual operating cost per passenger of an LRT line must be less than the annual operating cost per passenger of the existing bus service it replaces, when there is a clear service replacement. Otherwise, the annual operating cost per passenger must be less than the system average annual operating cost per passenger."

The complementary, nonqualifying criteria are as follows: "The total annual cost per passenger for the LRT line (including annualized capital costs and operating and maintenance costs) should be less than the annual cost per passenger of existing or proposed transit alternatives." "A proposed LRT line should be more cost-efficient than either the existing service it replaces or a non-LRT alternative." Specifically, then, costs and benefits should be calculated not only for the total system but also for its component markets.

Costs and benefits accruing to different institutions and equity can also be considered an issue. For example, transit users benefit from increased speed, comfort, and reliability; commercial real estate benefits from improved accessibility; corridor residents benefit from decreased air pollution. Adding these kinds of benefits and subtracting the costs to others will enhance the calculation's credibility and allow identification of sources of support or opposition.

Such funding sources as federal and state aid can also complicate the cost-effectiveness calculation. Two approaches are possible: to consider the total cost of the project as local expenditures or taxpayers' funds returned to the area; or to assume that either federal or state aid, or both, are gifts to the region. The second approach enhances the cost-effectiveness of high-capital-cost alternatives when capital grants are a significant factor, and affects the resulting decisions. The Twin Cities calculations assumed no outside aid and still found LRT cost-effective.

The Twin Cities tested the sensitivity of the cost-effectiveness to inflation assumptions by analyzing the impact of changing those assumptions. Other factors that can also be tested for sensitivity include premium fares, transfer costs, automobile use costs, parking availability, and local bus feeder systems. As these elements were held constant in comparing LRT with non-LRT alternatives in the Twin Cities, sensitivity tests were not done. These tests would be more appropriate to a more detailed analysis of a specific corridor.

Community Support

The success of major transportation investments depends on community support for the project. Local acceptance and commitment are critical to early implementation. In order to take this factor into consideration, the qualifying criterion developed in the Twin Cities study states: "Substantial commitment and support by the affected public and private sectors must be evident for the proposed LRT line."

This criterion requires that to be feasible the planning and implementation of an LRT line be supported by citizens, affected businesses, and public officials. This support must be demonstrated by actions and resolutions of city councils, county boards, chambers of commerce, community groups, and neighborhood organizations.

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Energy Implications of Rail Transit

MILTON PIKARSKY, IIT Research Institute

Whether mass transit actually saves energy is not easy to answer; different studies show different results. This paper reviews the major studies, notably the Congressional Budget Office's 1977 report, "Urban Transportation and Energy: The Potential Savings of Different Modes," and several studies done in response that debate many of its findings. A possible petroleum conservation strategy that focuses on future urban and regional development is identified and discussed.

The U.S. energy crisis is essentially a transportation crisis. In recent years the transportation sector accounted for one-fourth of all the energy used nationally—some 19.8 quadrillion Btu in 1979—and half of the petroleum consumption. Ninety-seven percent of the transportation sector's energy needs were supplied by petroleum in 1979.[1] Highway vehicles used 80 percent of this petroleum and private autos 70 percent. Natural gas accounted for 2.6 percent, mostly in pipeline consumption, although interest is now being renewed in the use of compressed natural gas and propane for vehicles. The electricity used was less than 1 percent, and most of this was used by fixed rail transit systems, which in 1978 used 2223.0 million kWh of electricity—about 7.5 trillion Btu. Buses used diesel oil and a small amount of gasoline, equivalent to about 60 trillion Btu in 1978.[2]

Total and per capita consumption in the transportation sector rose steadily through 1978 and fell sharply in 1979 despite increases in other sectors (Table 1[2]). In the first 9 months of 1980, gasoline consumption was 7 percent lower and imports of petroleum and products were nearly 20 percent lower than in the same period in 1979. This trend reflects a number of developments: sharply higher world oil prices, gradual deregulation of United States oil prices, and mandated automobile fuel efficiency standards of 20 mpg fuel average in 1980.

Additional factors will eventually affect energy use in the transportation sector, including development and use of alternative vehicles (e.g., the electric car), engines (e.g., the Stirling engine), and fuels (e.g., hydrogen, natural gas, ethanol, and methanol). Implementing existing and proposed energy efficiency standards for new automobiles (corporate average fleet efficiency), mandated to reach 27.5 mpg in 1985, will also reduce gasoline consumption. However, even if a fleet average of 24 mpg for all existing autos is achieved by 1990, the daily petroleum consumption is estimated to rise to 2.8 million bbl/day compared with 2.6 million bbl/day in 1975 when the fleet average was only 14 mpg.[3]

Another energy-saving transportation option is rail transit. Its energy-saving implications caused considerable controversy in the past few years, particularly as increased investment in mass transit has come under mounting criticism.

TRANSIT TRENDS

Only 16 of the 1003 transit systems in the United States in 1978 included heavy and/or light rail. Three systems consisted only of heavy rail and 948 only of motor buses.

Table 1. Sectoral primary energy consumption.

	Residential/Commercial		Transportation		Industrial
Year	Total 10^{12} Btu	Per Capita 10^6 Btu	Total 10^{12} Btu	Per Capita 10^6 Btu	Total 10^{12} Btu
1970	24 574	120.0	16 077	78.47	26 170
1971	25 540	123.4	16 671	80.52	26 086
1972	26 807	128.4	17 675	84.63	27 145
1973	27 396	130.2	18 525	88.04	28 685
1974	26 699	126.0	18 057	85.20	27 998
1975	26 635	124.7	18 186	85.15	25 881
1976	27 831	129.3	19 071	88.62	27 603
1977	28 193	130.0	19 751	91.06	28 442
1978	28 807	131.8	20 626	94.35	28 716
1979	29 369	133.2	19 786	89.74	29 627

Notes: Excludes natural-gas transmission losses and unaccounted-for-natural gas. These data include distributed electricity end uses converted at rates corresponding to national average thermal power plant performance. Per capita values calculated by the author.