Measuring Impacts of Transit Financing Policy in Geopolitical Context: Montreal Case

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Redistributive effects of transportation networks are difficult to appreciate with traditional models. Specifically, in a geopolitical context, such as the Montreal case in which the transit fare deficits are absorbed by local municipalities, there is a substantial disparity between funding allocations based on where riders live versus where they use the transit system. The actual research project suggest a new methodology articulated on processing origin and destination survey data with a totally disaggregate approach. The method calculates, for every transit line and bus route, transit consumption in terms of passenger kilometers traveled by respective municipality residents. A spreadsheet is then developed for allocation of costs and revenues against a suitable measure of direct benefits within a multinetwork, multimodal, and multi-institutional framework. In the Montreal context, economic distortions (typically, suburban riders being subsidized by the core city residents) have been observed with the studied (1987) fare-subsidy structure.

The greater Montreal area (GMA), composed of more than 100 municipalities that collectively make up a population of approximately 3 million, is served by 21 small intermunicipal transport corporations (CIT) in addition to three large transit operators (Figure 1). They are:

- STCUM: Montreal Urban Community Transit Corporation, which serves 28 municipalities on the central Montreal Island;
- STL: Laval Transit Corporation, which serves the city of Laval uniquely; and
- STRSM: Montreal South Shore Transit Corporation, which serves eight suburban municipalities on the South Shore.

Transit is funded according to the following ratio [using 1987 data, (*1*)]; fare revenues provide approximately 40 percent of the operating expenses, government subsidies provide approximately 35 percent, and the local municipality's contribution is 25 percent. This local contribution is obtained from taxes, which are for the most part based on land and property values. A generic problem arises from this context. When residents use transit networks outside their own municipality, there are economic impacts that are not necessarily compensated by reciprocal trips.

The topics addressed in this paper deal with the design of a methodological approach to measure urban travel demand (transit usage) in a multinetwork, multimodal, and multi-institutional environment. Two distinct problems arise from this approach: the measure of benefits, related to an urban transport system according to different categories of beneficiaries [direct (transit riders), indirect (employers, businesses), and nonusers (car drivers and passengers)] and the allocation of costs and revenues (fares, subsidies).

A classic informational setup, typical of the urban transport system planning approach, is built around territorial, network, and travel demand data. In the Montreal case, origin-destination (O-D) surveys undertaken in 1982 and 1987, with an average 5 percent sampling of households, are used to characterize O-D trips by mode (car, transit), purpose (work, study, other), geopolitical linking of trip origin, trip destination and residence, time of day (peak, off-peak), gender, and age (reduced fares). All transit networks and modes (train, subway, surface) are coded into a transit assignment framework. The assignment software used is Model for the Disaggregate Analysis of Urban Transport Itineraries (MADITUC), which has the ability to process disaggregate and observed trip data.

The experiments conducted with these planning tools have demonstrated that the Montreal Urban Community (MUC) suburban riders consume a significant amount of passenger kilometers on the core transit network, without any apparent economic compensation. With the objective of calculating the redistributive effects of the actual fare-subsidy structure, a spreadsheet model has been developed to test different allocation scenarios.

The first section of this paper presents the typical transit financing formula, the different actors involved, and the available urban transportation planning system. The next section describes the conceptual framework relative to measuring the benefits of a multinetwork transport system and the related data bases that are processed using the totally disaggregate analysis procedure. Finally, some simulation results are analyzed and put into perspective to obtain a more global and multimodal urban transportation approach.

TRANSPORTATION PLANNING INFORMATION SYSTEM

As outlined in the previous paragraphs, a transit system analysis focuses on the financing (sharing) formula, the different political actors involved, and the tools available to apply some form of a modeling structure among actors and related benefits and costs.

Transit Financing Formula for Montreal Case

The transit financing formula, as it existed and was applied in the 1980s, was mainly developed to cover the operating expenses, thus excluding capital expenditures such as infrastructure implementation (subway, garages) and vehicle acquisition. Every transit authority's operating revenue is derived from its own ridership and

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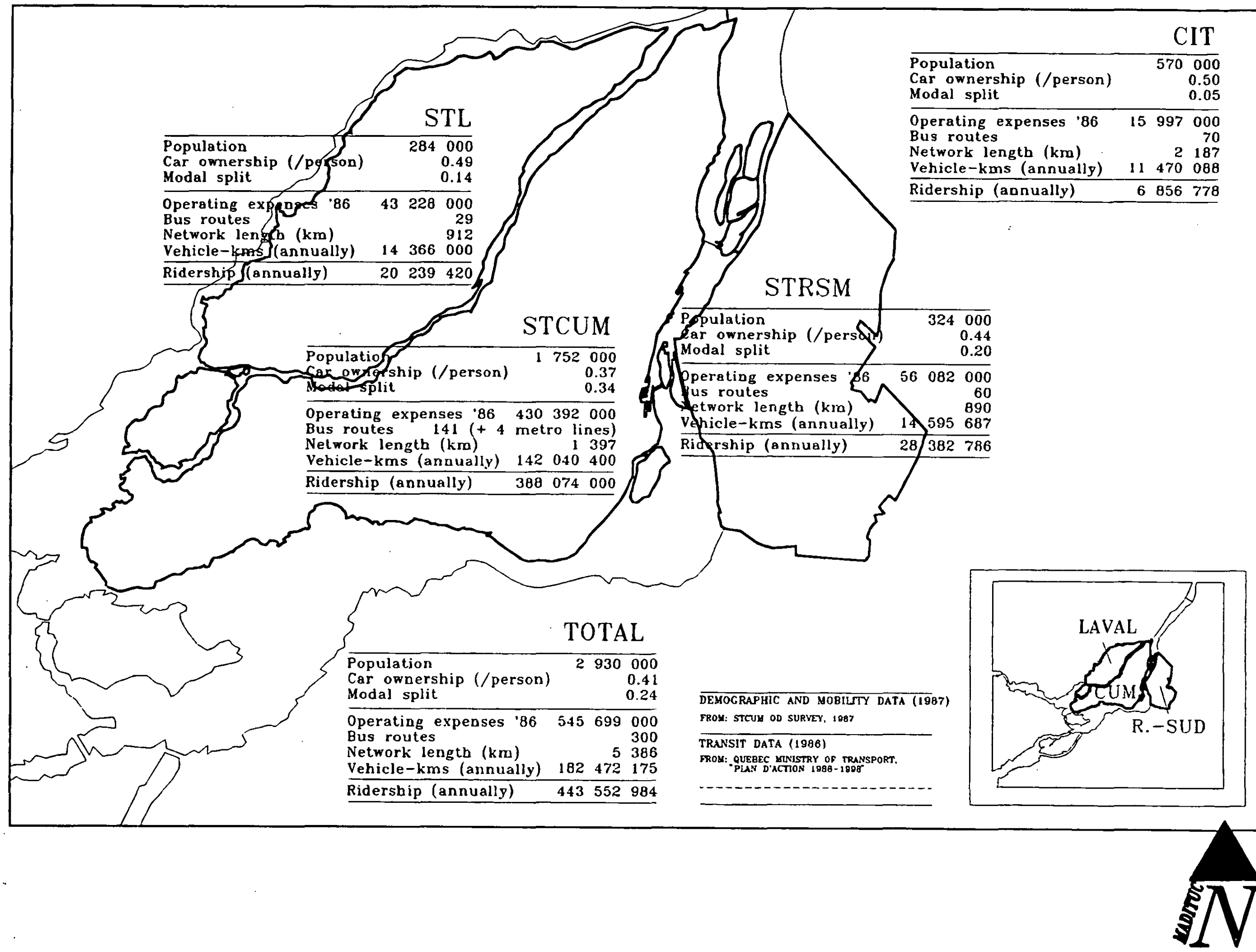

FIGURE 1 GMA transit authorities and related data.

from governmental subsidies, which are roughly proportional to ridership; the difference is compensated by the local government. The simplified model could be seen as:

$$\text{Municipal share} = \text{operating expenses} - \text{ridership} \cdot (\text{fare} + \text{subsidy})$$

This equation clearly shows that some conceptual problems may arise when the transit riders are not residents of the authority's governing municipalities or when some transit riders use more than one transit network (trip is twice subsidized by the provincial government).

With this fare structure, typical residents contribute, through taxes paid to their local government, only to the deficit of one transit authority (their own residential authority), even if they are working or studying in another geopolitical territory and, consequently, benefiting from external other transit services.

Depending on the respective consumption of different transit services, some geopolitical areas may suffer from nonsymmetrical situations; this is the case for the central area. Sociodemographic, spatiotemporal trends, as documented by Chapleau, Girard, and Lavigueur (*2,3*) indicate that the more affluent suburban areas are taking advantage of this sociofiscal escape.

Actors in Greater Montreal Area

In the GMA, provincial government subsidies are granted to transit operators, or equivalently, to the respective local governments (municipality or urban community) responsible for providing transit services in their territory. Fare integration is considered negligible for our purpose. Every transit authority applies its own fare structure on its network. Typically, in a given network, a single fare permits an unlimited number of transfers from origin to destination.

Urban Transportation Planning System

The analytical tools available in the GMA are derived from the compilation of 5 percent-sampled O-D surveys undertaken every 4 to 5 years by the STCUM, coupled with the MADITUC system (*4,5*). The related planning information system consists of the rigorous specification of all geopolitical areas in which each transit network is systematically defined in a regional context. O-D trips are validated over the entire regional network, and transit trip assignment procedures can generate results according to the usual totally disaggregate analytical approach.

The informational setup is composed of the following:

- Precise location data of trip origins and destinations, such as UTM (Mercator) *x-y* coordinates, Canadian postal code (blockface), or small zones (1,500 units for the GMA). These *territorial units*, after being used for precise calculation of walking times and access nodes, are to be aggregated to the most significant level of *geopolitical area*.
- Transit network characterization according to geometry, connectivity, and level-of-service, sufficiently detailed for the estimation of *passenger kilometers and passenger hours* consumed on an average weekday for every transport route and mode (train, subway, bus). About 300 transit lines are coded for the GMA.
- A data file containing all disaggregate O-D transit trip records, according to a data structure enabling the *tracking of every variable* associated with an individual trip. A schematic representation follows (Table 1).

CONCEPTUAL FRAMEWORK

Existing approaches for estimating financial impacts of transit usage are based on classic transit trip assignment procedures. Severe limitations are associated with the use of O-D matrices, particularly because the relationship between trip origin and traveler's residence is fairly weak; CBD origin trips, nonhome-based trips, and a large spectrum of activities are to be discarded in such an analysis. The traditional method lacks feedback mechanism to keep individual relationships among O-D trips, travel modal consumption, and individual personal travel behavior.

Disaggregate Trip-Processing Technique

The totally disaggregate urban transportation modeling approach deals with individual O-D trip records. Each procedure, such as access modeling, path calculation, or network loading, is considered an information additive operator, achieving supplementary interfaces with territorial and network data bases. A schematic of the data and file processing procedures is shown in Figure 2.

The three-step algorithm consists of

1. The calculation of *travel entities* (access and transfer nodes, route links) and *attributes* (walking, waiting, in-vehicle, and total travel times and distances), using the network *access* and trip *validation* (or minimum travel time path computation) procedures for every O-D transit trip.
2. The estimation of *modal usage* (train, subway, and bus) in terms of a transit authority's *ridership, multimodal passenger-hours*, and *passenger-kilometers*, using an *assignment* procedure.
3. *Data aggregation* into a relevant *geopolitical zoning system*, using a retroactive process over the residential zone variable, and the calculation of respective *network* (transit authority) and *mode* consumption by *residents* or any other suitable stratification variable.

Application to Direct and Indirect Transit Users

Instead of simply measuring the benefits from the perspective of the home-based or residential zone variable, the same method could be applied to any other variable or combination of variables. This *process* requires further elaboration on the usual concept of transportation network's benefits and its attribution. For example, *transit riders* benefit *directly* from the transit system; moreover, so does their *employer*, their *school*, or their *shopping center*. In the latter case, the third step, the retroactive process, should be applied to the variable pair *purpose-destination*. Any other study of the redistributive effects of a transit network, considering such variables as age or gender categories, income class, car ownership, and others may be similarly undertaken.

Potential Extensions to Car Users

There is no methodological limitation for considering other dimensions of the urban travel demand. The issues related to transit financing may integrate some measure of *indirect benefits to car drivers*. Two methods of measurement could be applied: (*a*) O-D trip assignment simulation (access, path calculation, network loading) of car users' trips over the regional transit network or (*b*) simulation over the regional road network and the calculation of travel attributes for each geopolitical territory (those corresponding to a transit authority's service area). The choice of method depends on the information system available for the specification of each network's respective interterritorial consumption.

Cost Allocation: Equal Costs and Reciprocity

As already shown, the disaggregate approach has the ability to compute precise travel attributes of individuals who benefit directly or indirectly from the transportation system and to make *relational links among geopolitical areas, transportation networks, and modes* (or routes). At this stage, the method establishes precise measures of travel demand such as volumes, passenger-kilometers, and maximum load, as well as such travel supply characteristics as the

TABLE 1 Schematic Representation of Disaggregate O-D Transit Trip Record

Origin Zone	Destin Zone	Flow	Residential Zone	Travel Purpose	Time Period	Transit Network Path/Time/ Distance
Precise measurement of trip characteristics for every Declared ITINERARY		Weight Expans. factor	Belonging to a Geopolitical Area	Employers Schools Businesses	Maximum Load Peak Off-Peak	Modal consumption Volumes, Pass-kms by Network by mode, by route

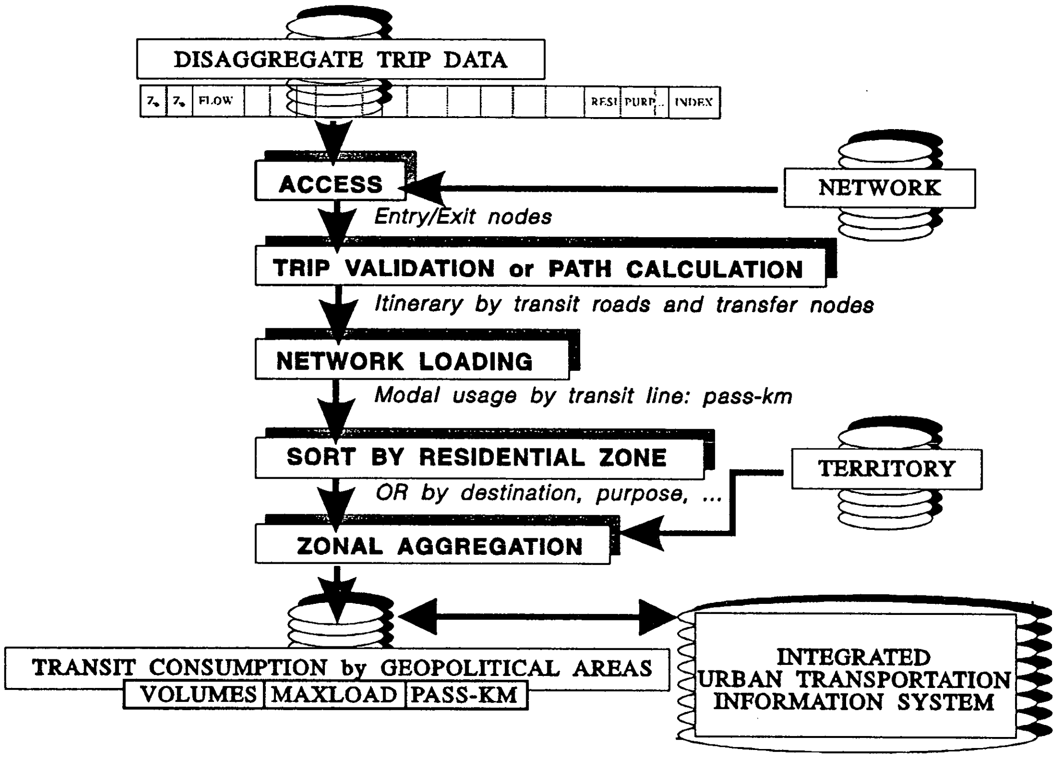

FIGURE 2 Disaggregate processing technique.

number of vehicles required and the number of vehicle-hours and vehicle-kilometers consumed. Classical costing procedures (*6*), often based on UMTA Section 15 data or any other Uniform Information System, are applied to operational data to derive relevant *unit costs*, average fares, and subsidies.

The costing exercise is a critical responsibility for the transportation analyst. Basic assumptions such as the application of the reciprocity principle and cost parity to all geopolitical areas and transportation users are obvious. However, the choice of the cost-fare-subsidy allocation criteria is more difficult. The following model leaves this choice under the control of the analyst. When financial data for each transit authority is available and segmented by operational revenues, total subsidies, and operating expenditures, some choice variables become natural.

INTEGRATED SPREADSHEET

The production of a transit authority is often measured in terms of the amount of vehicle-kilometers offered within a specific territory. A natural performance indicator should, then, focus on the passenger kilometers served. The value of transit usage may be considered proportional to this consumption variable.

Therefore,

Average unit COSTmode = operating expenditures/TOTAL pass-km served

On the other hand, fare revenue and subsidy are typically based on network ridership. For this variable, it is important to distinguish between *person trips* and *network trips* (and even mode or route trip) according to the applicable fare structure. Then:

Average unit FAREnetwork = network revenue/network ridership
Average unit subsidynetwork = network subsidy/network ridership

Application to Montreal Case

The GMA could be seen as being served by four networks. In the situation where only *transit usage* is selected as the basic factor to estimate the monetary value of the benefits generated to the residents of different geopolitical areas, a set of nonofficial data, which reflects the scope of the problem just the same, has been developed for this modeling exercise and is given in Table 2. Figure 3 illustrates the relative importance of transit usage by nonresidents. In the spreadsheet, the data are composed of the following for the 1987 base year.

- Annual financial data, with the distinction between *costs* (annual operating expenditures), operating *revenue*, and annual provincial government's operating *subsidy*. The *deficit*, the difference between costs and revenue + subsidy, is then assumed by the *geopolitical area* responsible for a specific network.
- Weekday transit usage data, derived from 5 percent sampled O-D surveys (STCUM, 1987) processed using the totally disaggregate approach of the MADITUC system over a 24-hr regional network including four subway lines (about 60 stations) and approximately 270 bus routes. Respective mode and network riderships (nonadditive *volumes*) of passenger kilometers traveled by residents of the following four geopolitical areas are calculated:
  - MUC responsible for the STCUM,
  - Montreal's South Shore, a group of eight municipalities managing the STRSM,
  - Laval, a city with the STL as its transit authority,

TABLE 2 Financial and Transit Usage Data (Montreal)

Financial Data ($Millions)*

1987	COSTS	REVENUE	SUBSIDY	MUNIC SHARE
S.T.C.U.M.-Subway(Métro)	296.6			
S.T.C.U.M.-Bus	306.2			
S.T.C.U.M. (All operations)	602.8	206.6	254.9	141.3
S.T.R.S.M.	58.8	20.4	21.7	16.7
S.T.L.	44.1	16.5	14.1	13.5
C.I.T.	21.2	10.9	5.6	4.7
TOTAL	726.9	254.4	296.3	176.2

* non official data

Transit Usage Data

	Volumes 24 hrs					Pass-km 24 hrs				
	RESIDENTIAL AREA					RESIDENTIAL AREA				
1987	M.U.C.	S.Sh.	Laval	C.I.T.	Tot.	M.U.C.	S.Sh.	Laval	C.I.T.	Tot.
S.T.C.U.M.-Subway	544137	57621	31217	24432	657407	3760747	388612	289612	205055	4644026
S.T.C.U.M.-Bus	825017	16301	15364	8721	865403	3705447	49514	52305	69745	3877011
S.T.C.U.M. (1)	1001776	59341	37397	27027	1125541	7466194	438126	341917	274800	8521037
S.T.R.S.M.	4503	103743	64	1578	109888	28361	889055	213	14183	931812
S.T.L.	4157	143	56255	1731	62286	38712	1556	462167	22229	524664
C.I.T.	965	538	618	19027	21148	24962	9674	7600	354525	396761
All transit authorities	1002487	116164	67454	36760	1222865	7558229	1338411	811897	665737	10374274

Unit Costs ($)

	Volumes 24 hrs					Pass-km 24 hrs				
1987	COSTS	REVENUE	SUBSIDY	MUNIC	per RES RIDERS	COSTS	REVENUE	SUBSIDY	MUNIC	per RES RIDERS
S.T.C.U.M.-Subway	451 $					64 $				
S.T.C.U.M.-Bus	354 $					79 $				
S.T.C.U.M. (Sub.+ bus)	536 $	184 $	226 $	126 $	**141 $**	71 $	24 $	30 $	17 $	**19 $**
S.T.R.S.M.	535 $	186 $	197 $	152 $	**161 $**	63 $	22 $	23 $	18 $	**19 $**
S.T.L.	708 $	265 $	226 $	217 $	**240 $**	84 $	31 $	27 $	26 $	**29 $**
C.I.T.	1 002 $	515 $	265 $	222 $	**247 $**	53 $	27 $	14 $	12 $	**13 $**
All transit authorities	**594 $**	**208 $**	**242 $**	**144 $**	**144 $**	**70 $**	**25 $**	**29 $**	**17 $**	**17 $**

- CIT, a group of 21 intermunicipal corporations serving a large number of municipalities on the north and the south shores of the Montreal area.

Accordingly, unit values are calculated for operating costs (average annual unit cost per regular weekday transit rider) and other variables: average annual fare, average annual subsidy, and average local share per rider. A separate column shows a distinct estimate based on the municipal share divided by the number of actual transit riders who are residents of the same geopolitical area. Some interesting facts are derived from the table figures:

- Fare revenues account for only 35 percent;
- Provincial subsidies account for 41 percent of the operating expenditures, and local governments contribute only 24 percent, in comparison to the Toronto case, which has the financing policy of 68 percent-16 percent-16 percent (fares, provincial, local) for operating expenditures. The situation has since drastically changed in Quebec; as of 1992, the provincial government had almost stopped granting its operating subsidies;
- Seventeen percent of the subway ridership and 19 percent of the consumed passenger kilometers are generated by nonresidents of the Montreal Urban Community. Moreover, non-residents contribute to only 11 percent of the total ridership of the STUCM. Consequently, nonresidents are found to travel longer distances at

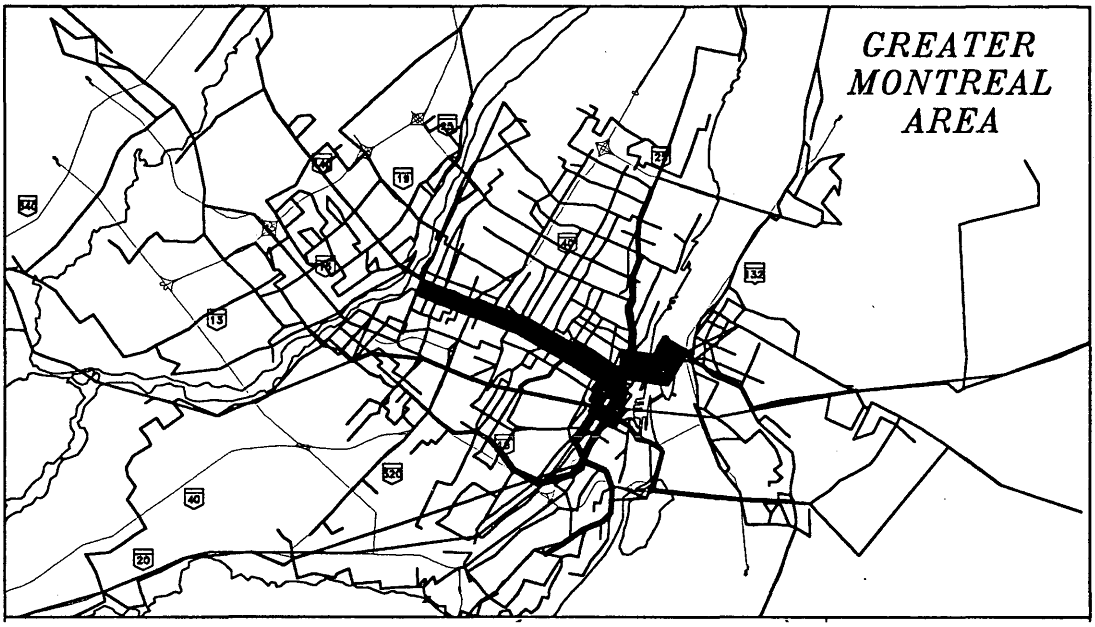

FIGURE 3 Relative importance of transit ridership by nonresidents.

higher speeds, providing proportionally less revenue and thus not contributing to the local municipal share.

Calculation of Geopolitical Financial Distortions

The application of the stated rules provides a means to estimate the relative values of cost, revenue, and subsidy that should be attributed to the residents of every geopolitical area. Table 3 sketches summary results based on the data previously shown:

- *Average annual transit consumption* for a resident of a specific territory. The second row represents the unit cost for a passenger-kilometer per resident. For instance, the MUC residents consume an overall value of $539 million (M) and the STUCM budget accounts for $602M, the difference of approximately $63M equally consumed by the other three areas: the South Shore ($26M), Laval ($18M), and the CIT ($19M).
- *Average annual fare contributed* by each resident. Results show a uniform average fare per passenger-kilometer for all geopolitical areas.
- *Average provincial government subsidy attributed* to a specific resident on the same basis as fare (ridership). Surprisingly, the average subsidy per resident transit rider is minimal for the central area, where the average income is known to be lower by a margin of at least 20 percent. Not surprisingly, the unit subsidy per passenger-kilometer decreases with the travel distance from the CBD.

Finally, the last figures concern the derivation of the fair municipal share, computed from the difference between the costing value of consumed transit by the residents and the sum of fare and subsidy revenues generated by their corresponding transit usage for every geopolitical area. Clearly:

Municipal sharearea = COST − (FARE REVENUE + SUBSIDY)

When consolidating the fair municipal shares for every combination of network and geopolitical area, differences appear between the amount actually attributed to the transit operator and the amount that should be fairly applied to the transit usage. That final amount, called a financial distortion, is negative for the CUM (−$17M) and should be compensated by the other geopolitical authorities at the indicated level.

CONCLUSIONS

This paper has demonstrated a consistent and coherent approach to address transit financing issues in a multigeopolitical urban context using a methodology (totally disaggregate approach applied to home-based O-D survey data) enabling the transportation analyst to take into account a large spectrum of variables and cost allocation scenarios.

When applying a limited-scope cost allocation scenario, that is, considering only transit usage (direct beneficiaries) for the Montreal case, financial distortions were calculated, thus suggesting the creation of a compensation mechanism among the several geopolitical areas of the metropolitan region. In fact, since 1989, there has been a commission called the Conseil Métropolitain du Transport en Commun, grouping the STCUM, the STRSM, and the STL, whose mandate consists of administrating fare integration (regional monthly pass) and some service coordination among the three larger transit operators. The provincial government has contributed a global annual subsidy of $25M for a limited period of 5 years. The proposed analytical methodology, when applied solely to the examination of the transit system of a metropolitan area, takes into consideration about only 25 to 30 percent of the personal motorized trips.

A better knowledge of the multimodal urban transport consumption in a metropolitan area, respective to geopolitical areas and direct-indirect beneficiaries, should lead to a better understanding of the underlying economic issues of transportation networks. How-

TABLE 3 Summary Transit Financial Calculation for Geopolitical Areas

Transit Consumption	M.U.C.	S.Shore	Laval	C.I.T.	Total-GMA
Consolidated TOTAL	539.2	85.5	61.9	40.3	**726.9**
NET value - network	-63.6	26.7	17.8	19.1	**0.0**
per resident transit rider					
Unit consumption per rider	538 $	736 $	918 $	1 097 $	**594 $**
Unit Cons. per Pass-km	71 $	64 $	76 $	61 $	**70 $**
Unit Fare per rider	186 $	262 $	328 $	422 $	**208 $**
Unit fare per Pass-km	25 $	23 $	27 $	23 $	**25 $**
Unit Subsidy per rider	228 $	294 $	317 $	323 $	**242 $**
Unit Subsidy per Pass-km	30 $	25 $	26 $	18 $	**29 $**
average F+S per rider	414 $	556 $	645 $	745 $	**450 $**
average F+S per Pass-km	55 $	48 $	54 $	41 $	**53 $**

Costs - (Revenue + Subsidy) ($ M)

Fair Municipal Share	RESIDENTIAL AREA M.U.C.	S.Shore	Laval	C.I.T.	Total-GMA
S.T.C.U.M. (Subway +bus)	122.1	4.4	7.3	7.5	**141.3**
S.T.R.S.M.	0.1	16.4	0.0	0.3	**16.7**
S.T.L.	1.2	0.1	11.2	1.0	**13.5**
C.I.T.	0.6	0.1	-0.1	4.1	**4.7**
Consolidated TOTAL	123.9	20.9	18.4	12.9	**176.2**
Financial Distortion	**-17.4**	**4.2**	**4.9**	**8.2**	0.0
Unit local share per rider	124 $	180 $	273 $	352 $	**144 $**
Unit local share per Pass-km	16 $	16 $	23 $	19 $	**17 $**

*** unit costs per rider in xx$**
*** annual costs in xxMillions**

ever, from a geopolitical standpoint, it seems that it may take a long time before issues of equity, in a world with sociodemographic and economic disparities spatially exacerbated by continuous urban sprawl and related land use management policy, should suggest to integrate car usage in a multimodal approach to transit system financing.

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