Some observations on evaluation methods pertinent to selection of a public urban transport system

by

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FOCUS OF THE STUDY

Recent problems of urban transport are a combination of various factors such as accidents, road congestion, and air and noise pollution, as well as demands for much more sophisticated services which acknowledge the needs of users, society and the operators. Problems no longer are confined to system management and carrying capacity improvement.

Therefore, at the time of selection or development of a new urban transport system, every possible factor shall have to be taken into consideration, not only the exact estimation of future needs but also the interrelationship among users, society and the operators. A new system cannot be satisfied with only an evaluation of technical feasibility but must be assessed systematically in reference to society and the economy.

For assessment of society and the economy in the selection of a new system, enough consideration should be given to the financial situation of the users or society involved, their sentiment, and their historical or traditional tendencies. In addition, assessing what the users and inhabitants expect from a system is necessary to estimate possible traffic demands.

Furthermore, it is necessary to develop a theory for the quantitative analysis of the items for evaluation, and to develop methods for the quantitative analysis of the correlativity between the social situation for the users and their preference in transport modes.

This paper, in recognition of such necessity, will discuss the "Utility Function" method users in quantitative analysis pertaining to selection of a public urban transport system, and the applicability of the "Utility Function", by means of some case studies.

ITEMS FOR EVALUATION

In conjunction with the above, the establishment of newly created items for evaluation was planned with an emphasis on simplifying recognition in relation to the study of a methodology. At the same time, it was acknowledged that coverage under the new items for evaluation would have to accommodate many diverse aspects.

In defining the 'interest group' in evaluation of the transport system (as groups categorized in reference to the interests involved), it will be composed mainly of the 'users', 'society', and 'operators'. Items for evaluation on each of these parties were made as follows:

A. Items to be evaluated by "USERS"

Rapidity
- Rapidity

Convenience
- Punctuality
- Operation reliability
- Entrance and exit simplicity
- Walking distance
- Waiting time
- Train and line transfer simplicity
- Sheltered station availability
- Early morning services
- Late night services

Riding comfort
- Internal car noise
- Vibration
- Views from the windows
- Insurance of privacy
- Degree of congestion
- Seating capacity and adequacy
- Air conditioning

B. Items to be evaluated by "SOCIETY"
- Noise
- Air Pollution
- Structure occupancy capacity (above surface)
- Degree of intrusion into privacy
- Physical and social division of community

C. Items to be evaluated by "OPERATORS"

Construction costs
- Laying of rails
- Construction of stations and relevant structures
- Aerial or ground wiring provisions
- Provisions for car yards
- Transformer substations construction
- Provisions for train control systems
- Inspection and administration

Operational costs
- Personnel expense
- Maintenance of cars and vehicles
- Maintenance of rails
- Maintenance of aerial or ground wiring
- Electric supply expense
- Administrative expense

In general, items for the users are categorized by five factors; namely passenger fare, rapidity, safety, convenience and comfort. But, in the case of Japan, rail fares cannot be decided by independent action, the public railroad enterprise being overseen and subsidized by the government. Accordingly, passenger fares for the operators have been excluded from corresponding items in lists "A" and "C".

In respect to safety, it is assumed that there are no safety differences between the transport systems, with the understanding that the safety of any public transport system would have to exceed a regulation standard. Therefore, the cost of safety was included in the operational costs.

Regional societies concerned here are, by the development and installation of the new system, to take advantage of an improvement in economic and social status, while at the same time assuming the disadvantages of being exposed to environmental air and noise problems as well as the inevitable physical and social separation of the society.

The potential involved in this area is the greatest of all. It can be subdivided into categories of 'health', 'right-of-way' (right to compensation from society separation), 'effects on the economy', 'effects on city deformation', and 'effects on politics and the society'.

Since establishing the quantitative analysis method was the major requirement, the number of items concerning the evaluation of regional societies were simplified to the smallest practical number.

Therefore, it would appear that evaluation of the regional society in this study emphasized the disadvantageous aspects but it should also be considered that the advantages of regional and other economies would be considerable.

Concerning the evaluation of the operators, only major items relative to profitability were considered. Consequently, the comparison of expenses was incorporated, but revenue determination was excluded, due to the differences explained before.

Generally, considerations as to the degree of difficulties of construction and securing of experienced workers, as well as the consistency and discretion of the management, were incorporated.

METHOD OF EVALUATION

Assessment was made on the users' evaluation and preference toward each of the items of a transport system, after which the results were incorporated in a summary of system comparisons.

"Preference" is an expression of the users', psychological judgement based upon their value opinions, the quantitative value of which is designated as "Utility". "Utility Function", therefore, represents the situation where the users' attitude toward each item would be reflected by means of individual review and replies to a questionnaire.

"Weight of importance" among the items was set in conjunction with the "Utility Function", thus the 'total utility' was determined as the sum total of all items, as shown in Formula - 1, hereunder:

$$U = \sum_{i=1}^{n} W_i \times U_i \qquad (1)$$

where,

U	:	Utility for user
i	:	Item of evaluation by user
n	:	Number of items evaluated by user
U_i	:	Utility Function of item 'i'
W_i	:	Weight of importance of item 'i'

This formula is applicable to the assessment of the utility for an individual person. For the assessment of the utility for a group of people, it can be determined by adding up each individual value of 'U' which in turn is obtained by applying each variable to the function 'U_i' in accordance with the values estimated on each type of trip by individuals (such as origin and destination, time of trip, distance to the station, etcetera).

The "Utility Function" on the evaluation of the society is almost equivalent to that for users. However, it should be noted that each item of evaluation has its own range of coverage, or expressed alternatively, the range of people to be involved in the evaluation differs from item to item.

Thus, the "Utility Function" for the society evaluation is to replace 'i' in the formula - 1 by the item 'j' of the items in the society evaluation. Thereupon the degree of regional largeness and the population density shall be taken into consideration for the calculation of 'U_j'.

Expenses will only be items for operator evaluation. Therefore, it would not be necessary to convert "expenses" into "utility" but to compare the extent of expenses in a direct way, in order to make an independent evaluation of each of the three parties involved.

The "evaluation function" is therefore to discuss the 'annual costs' as shown in Formula - 2, hereunder:

$$\left.\begin{aligned} TC &= CC + OC \\ CC &= \sum_{k=1}^{m} \frac{I\,(1+I)^{Y_k}}{(1+I)^{Y_k} - 1} \times C_k \end{aligned}\right\} \qquad (2)$$

where,

TC	:	Annual costs
CC	:	Annual capital costs
OC	:	Annual operational costs
k	:	Item of construction costs
m	:	Number of items of construction costs
C_k	:	Construction cost of Item 'k'
Y_k	:	Life of 'k' facility
I	:	Interest rates

The execution of 'systematic evaluation' is deceptive in that the parties, namely the users, society and the operators, could take positions opposed to each other. Therefore, it would be preferable to consider that the overall or eventual evaluation, including the processing of evaluation values on the peripheral situations, should be removed from the quantitative analysis and placed in a superior field for judgement.

In conformity with this thinking, the results of the evaluation have incorporated an illustrative example to augment this study. While the illustration includes each of the three parties, summation of the information is not analytic but descriptive in nature.

CASE STUDIES OF URBAN TRANSPORT SYSTEMS

A series of case studies were conducted on urban transport systems with the application of quantitative analysis by "Utility Function". The situation where new transport systems could be introduced was categorized into seven patterns according to factors of origin and destination, trip distances and others.

To manage the population concentration in the big cities and the consequent shortage of living space, many new towns (bed towns) were developed in suburban areas of large cities in this country.

The following is an example of one study conducted for the evaluation of an urban transport system linking a medium-sized new town with an adjacent railway station.

For provision of transport between this new town and an adjacent railway station on a trunk line, it was found imperative to develop and introduce a new kind of transport system. This was necessary because the construction of a new rail line would be too expensive for uncertain transport demands while bus transport ability was termed inadequate.

Assuming the situation that a new town of about 50,000 population located approximately five kilometers from the nearest railway station on a trunk line, an evaluation was made for the possible choices of connecting transport. But services and the introduction of a "medium traffic rail transport" system (which is being developed in this country) were compared.

Three types of bus services were considered;
1) bus service given an exclusive express lane,
2) bus service on an exclusive, elevated road and
3) dual-mode urban electric bus service.

Following is an illustrated representation of the systems analysis results in reference to evaluations of the three parties involved - the users, society and the operators.

Outward direction of each axis represents the negative effect as well as the scale of monetary investments involved, setting the standard on the development of the system by the aforementioned "medium traffic rail transport".

Deducible from the situation is the conspicuous relationship between the society and the operator where the situation of "trading off" (too good for one is too bad for the other) is apparent. This will show the applicability of the evaluation analysis by "Utility Function" to the extent evaluation of public transport would be satisfied.

CONCLUSION

This study for the development of a method of evaluation for the selection of a public urban transport system seems to be valuable in its basic concept, but it should be emphasized that further studies are necessary to increase the range of applicability.

ACKNOWLEGDMENTS

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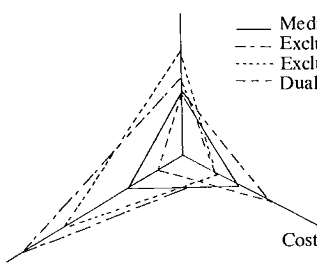

SUPPLEMENT

FIG 1
APPLICATIONS OF NEW TRANSPORT SYSTEMS
(Examples)

Pattern Of Transport \ System Concept	Railway System	Non-Railway System	Dual-Mode System	Continuous System
1. Suburbs—Center	Fast Intraurban Transit (FIT) Monorail	——	Dual-Mode Bus (DMB)	——
2. Airport—Center	FIT Monorail	——	DMB	——
3. New Town	Intermediate-Capacity Transit (ICT) Monorail	Dial-a-Bus	DMB	——
4. Central Business District	Personal Rapid Transit (PRT)	Minibus City Car	——	Moving Way High-Speed Continuous System (HSCS)
5. Airport Or Terminal	ICT	——	——	Moving Way HSCS
6. Access (in the suburbs)	ICT Monorail PRT	Dial-a-Bus Minibus City Car	DMB	——

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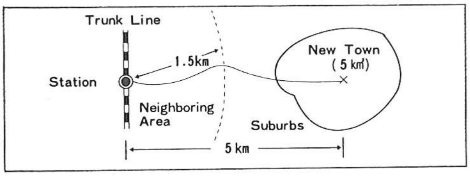
FIG 2
AREA OF THE CASE STUDY



● Population	Residents	50,000
	(Commuters	20,000)
● Density of Population	New Town	10,000/km²
	Suburbs	2,000/km²
	Neighboring Area	8,000/km²
● Demand	Peak (4 hours, one way)	7,500/hour·line
	Off-peak (14 hours, both ways)	< 375/hour·line
● Modal Split	Transit System	75%
	Other Systems	25%

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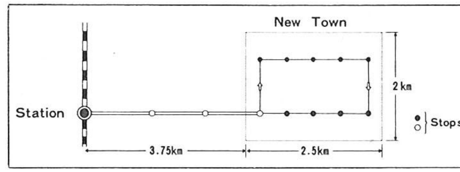
FIG 3
ROUTE AND CHARACTERISTICS OF THE INTERMEDIATE-CAPACITY TRANSIT (ICT)



● Location Of Stops:

- Access Time In the New Town .... 5.5min. (Mean)
- Changing Time At the Station .... 2min.

● Vehicle And Guideway:

- Capacity Of a Car .... 30 (11 Seats)
- Support .... Air Tire On a Concrete Surface
- Drive .... Rotary Electric Motor
- Air Conditioning .... Both Heating And Cooling
- Guideway ....Elevated (5 m) Concrete Way

● Operation:

- Service Time .... From 6:00A.M. Till 12:00 P.M.
- Headway At a Peak Time .... 1.5min. / 3.0min. / 5.0min.
- Overcrowding At a Peak Time .... 100% / 150%
- Delay .... About 5 min., Once a Month
- Speed .... 40km/h / 50km/h / 60km/h

③

FIG 4-1
AN INTERMEDIATE-CAPACITY TRANSIT IN A NEW TOWN

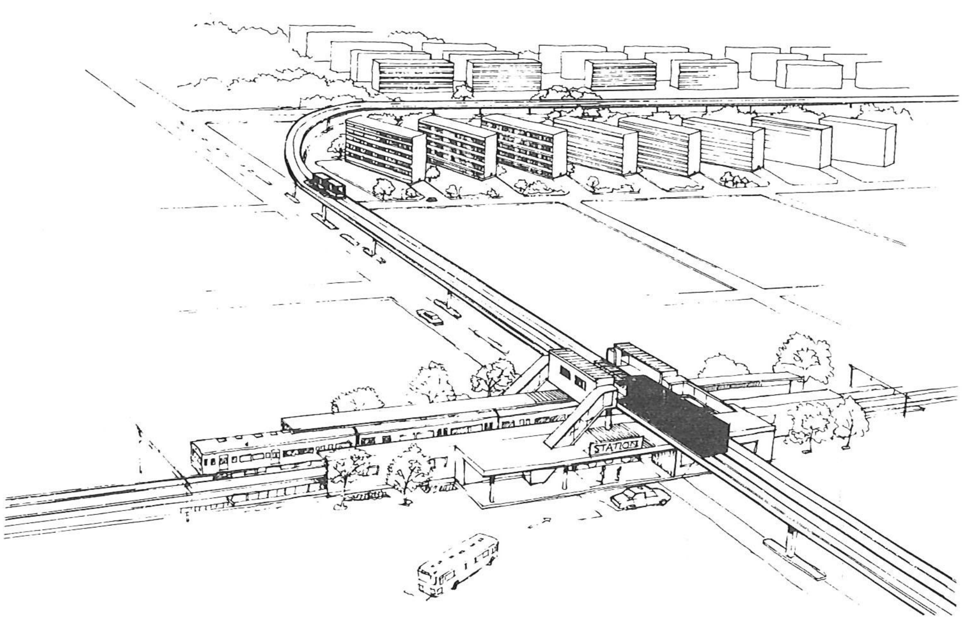


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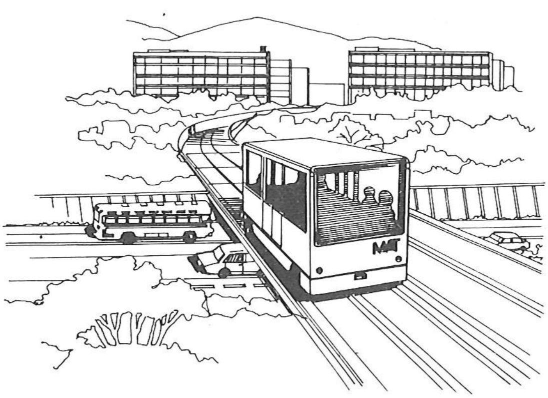
FIG 4-2
VIEWS OF AN INTERMEDIATE-CAPACITY TRANSIT

(A)



(B)

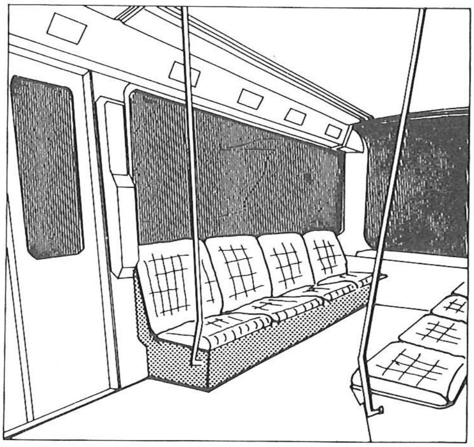


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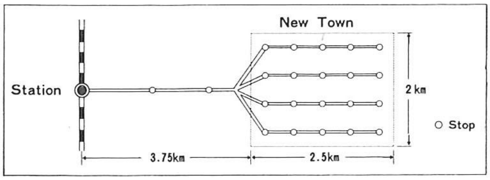
FIG 5
ROUTE AND CHARACTERISTICS OF THE EXCLUSIVE-LANE/ROAD BUS (ELB/ERB)



● Location Of Stops:

Access Time In the New Town ················ 3.1 min. (Mean)
Changing Time At the Station ················ 4 min.

● Vehicle And Guideway:

Capacity Of a Car ···················· 80 (40 Seats)
Support ················ Air Tire On a Road Surface
Drive ···················· Diesel Engine
Air Conditioning ················ Heating Only
Guideway (Out Of the New Town)
- ELB ········ Exclusive Lane (Ground Level)
- ERB ········ Elevated Exclusive Road

● Operation:

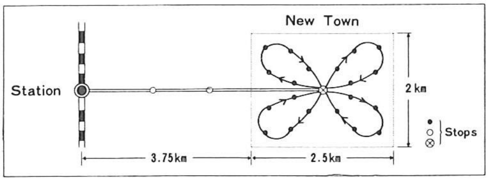
Service Time ········ From 6:00 AM. Till 12:00 P.M.
Headway At a Peak Time ········ 2 min. / 2.5 min. / 3 min.
Overcrowding At a Peak Time ············ 100%
Delay
- ELB ········ About 10 min., 4 Times a Month
- ERB ········ About 7 min., 3 Times a Month

Speed (Out Of the New Town)
- ELB ········ 20 km/h
- ERB ········ 40 km/h

Operator ················ One-Man System

⑥

FIG 6
ROUTE AND CHARACTERISTICS OF THE DUAL-MODE BUS (DMB)



● Location Of Stops:

Access Time In the New Town ················ 3.1 min. (Mean)
Changing Time At the Station ················ 2 min.

● Vehicle And Guideway:

Capacity Of a Car ················ 30 (11 Seats)
Support ············ Air Tire On a Concrete Surface
Drive ················ Rotary Electric Motor
Air Conditioning ········ Both Heating And Cooling
Guideway (Out Of the New Town) ········ Elevated Electric-Supplied Way
Power (In the New Town) ········ Storage Battery

● Operation:

Service Time ········ From 6:00 A.M. Till 12:00 P.M.
Headway At a Peak Time ········ 2 min. / 3 min. / 5 min.
Overcrowding At a Peak Time ········ 100%/150%
Delay ················ About 7 min., Twice a Month
Speed (Out Of the New Town) ············ 40 km/h
Operator
- In the New Town ········ One-Man System
- Out Of the New Town ···· Automatic System

⑦

FIG 7
ITEMS TO BE EVALUATED BY USERS

Rapidity	• Rapidity (Travel Time)
Convenience	• Punctuality
	• Operation Reliability
	• Entrance And Exit Simplicity
	• Walking Distance (Time)
	• Waiting Time
	• Train And Line Transfer Simplicity
	• Sheltered Station Availability
	• Early Morning Service
	• Late Night Service
Riding Comfort	• Internal Car Noise
	• Vibration
	• Views From the Windows
	• Insurance Of Privacy
	• Degree Of Congestion (Overcrowding)
	• Seating Capacity And Adequacy
	• Air Conditioning Availability

⑧

FIG 8
EVALUATING FUNCTION FOR USERS

$$U=\sum_{k=1}^{N}\sum_{j=1}^{n}W_j\cdot U_j\ (X_j\ (k))\ \cdots\cdots\cdots (1)$$

Where, U : Total Utility For Users

j : Item Of Evaluation By Users

n : Number Of Items Evaluated By Users

k : Individual User

N : Number Of Users

W_j : Weight Of Importance Of Item "j"

U_j : Utility Function Of Item "j"

X_j (k) : Characteristics Of the System Pertinent To Item "j" And Individual User "k"

⑨

FIG 9-1
UTILITY FUNCTIONS FOR USERS

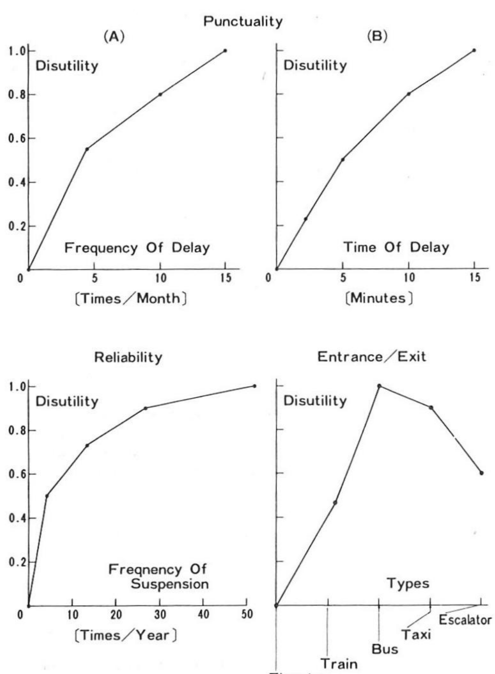


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FIG 9-2
UTILITY FUNCTIONS FOR USERS (Continued)

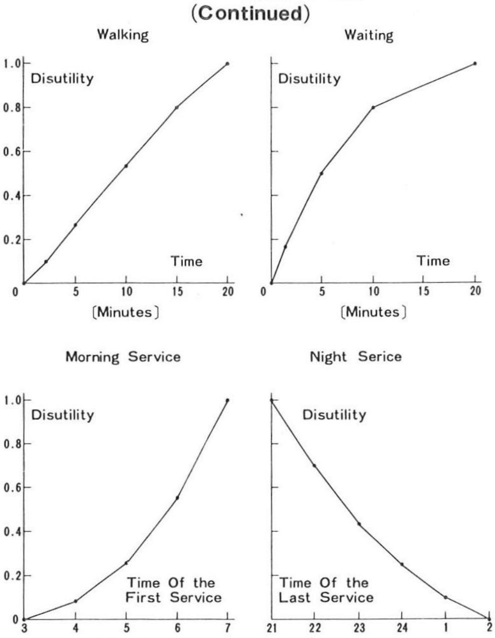

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FIG 9-3

UTILITY FUNCTIONS FOR USERS (Continued)

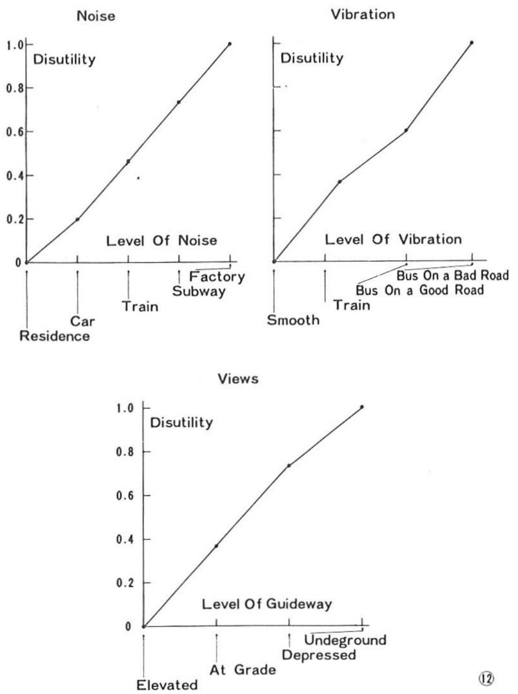

FIG 9-4

UTILITY FUNCTIONS FOR USERS (Continued)

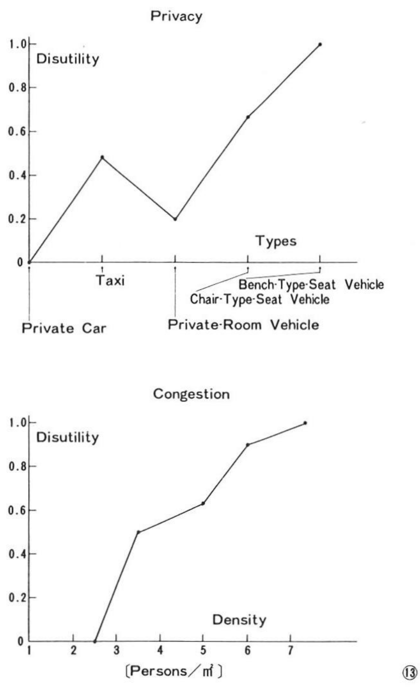

FIG 10

WEIGHTS OF IMPORTANCE OF ITEMS TO BE EVALUATED BY USERS

Items	Weights		Improvements Of a System
	To Attend	To Return	
Rapidity (Time)	•164	•146	60min → 45min
Punctuality	•178	•132	15min×2/w → No Delay
Reliability	•156	•133	Once a Month → Once a Year
Entrance / Exit	•085	•083	Bus → Elevator
Walking	•128	•125	15min → 5 min
Waiting	•155	•151	15min → 2 min
Transfer	•126	•123	1 → 0
Shelter	•119	•116	No → Equipped
Morning Service	•078	—	7:00A. M. → 4:00A. M.
Night Service	—	•140	9:00P. M. → 2:00A. M.
Noise	•125	•130	Sudway → Not Felt
Vibration	•128	•134	Bus On a Bad Road → Not Felt
Views	•096	•100	Underground → Elevated
Privacy	•084	•088	Bench-Type-Seat Vehicle → Private Car
Congestion	•142	•149	Jammed → Straps Occupied
Seating	•157	•165	Standing → Seated
Air Conditioning	•139	•145	Only Heating → Heating & Cooling

⑭

FIG 11
ITEMS TO BE EVALUATED BY SOCIETY

- Noise
- Air Pollution
- Structure Occupancy Capacity (Above Surface)
- Intrusion Into Privacy
- Physical And Social Division of Community

⑮

FIG 12
EVALUATING FUNCTION FOR SOCIETY

$$U=\sum_{j=1}^{n} W_j \cdot \iint U_j\left(X_j(x,y)\right)\cdot P(x,y)\,dx\,dy \quad \cdots\cdots\cdots\cdots (2)$$

Where, U : Utility For Society

j : Item Of Evaluation By Society

n : Number Of Items Evaluated By Society

W_j : Weight Of Importance Of Item "j"

U_j : Utility Function Of Item "j"

$X_j(x,y)$: Characteristics Of the System Pertinent To Item "j" And Spot (x, y)

$P(x,y)$: Density Of Population Pertinent To Spot (x, y)

⑯

FIG 13-1
EVALUATING FUNCTIONS FOR SOCIETY

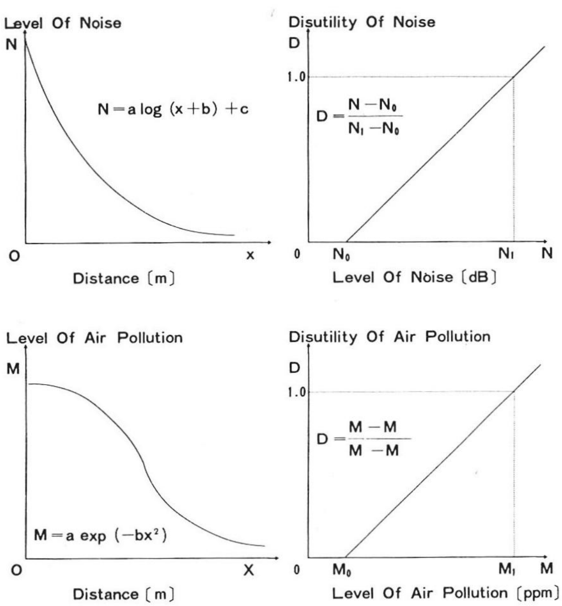

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FIG 13-2
EVALUATING FUNCTIONS FOR SOCIETY (Continued)

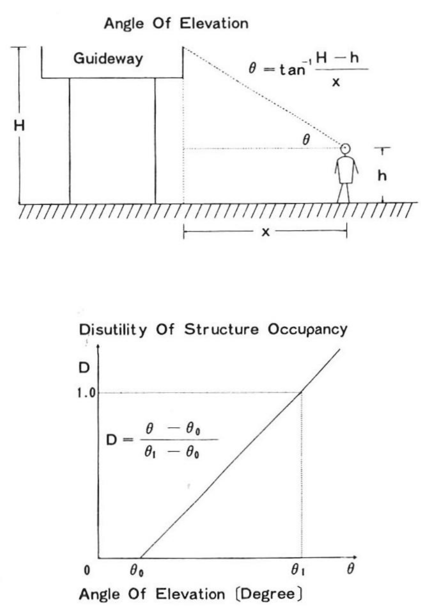

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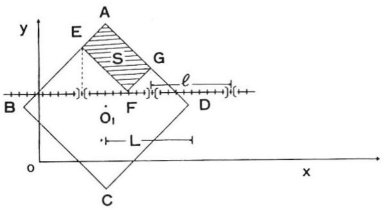
FIG 13-3
EVALUATING FUNCTIONS FOR SOCIETY (Continued)

Loss Of Community (S)



L: Extent Of Community ℓ: Interval Of Crossings

Disutility Of Division Of Community

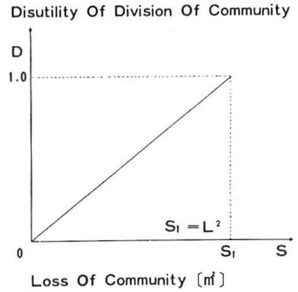


FIG 14
WEIGHTS OF IMPORTANCE OF ITEMS TO BE EVALUATED BY SOCIETY

Items	Weights
Noise	.245
Air Pollution	.241
Structure Occupancy Capacity	.198
Intrusion Into Privacy	.176
Division Of Community	.140

⑳

FIG 15
ITEMS TO BE EVALUATED BY OPERATORS

Construction Costs
- Laying Of Rails
- Construction Of Stations And Relevant Structures
- Aerial And Ground Wiring Provisions
- Provisions For Cars And Vehicles
- Provisions For Caryards
- Transformer Substations Construction
- Provisions For Train Control Systems
- Inspection And Administration

Operatioral Costs
- Personnel Expense
- Maintenance Of Cars And Vehicles
- Mairtenance Of Rails
- Mairtenance Of Aerial And Ground Wiring
- Power Expense
- Administrative Expense

㉑

FIG 16
EVALUATING FUNCTION FOR OPERATORS

$$TC = CC + OC \quad \cdots\cdots (3)$$

$$CC = \sum_{j=1}^{n} \frac{I\,(1+I)^{Y_j}}{(1+I)^{Y_j} - 1} \cdot CC_j \quad \cdots\cdots (4)$$

$$OC = \sum_{k=1}^{m} OC_k \quad \cdots\cdots (5)$$

Where,
- TC : Annual Total Costs
- CC : Annual Capital Costs
- OC : Annual Operational Costs
- j : Item Of Construction Costs
- n : Number Of Items Of Construction Costs
- CC_j : Construction Cost Of Item "j"
- Y_j : Life Of "j" Facility
- I : Rate Of Interest
- k : Item Of Operational Costs
- m : Number Of Items Of Operational Costs
- OC_k : Operational Cost Of Item "k"

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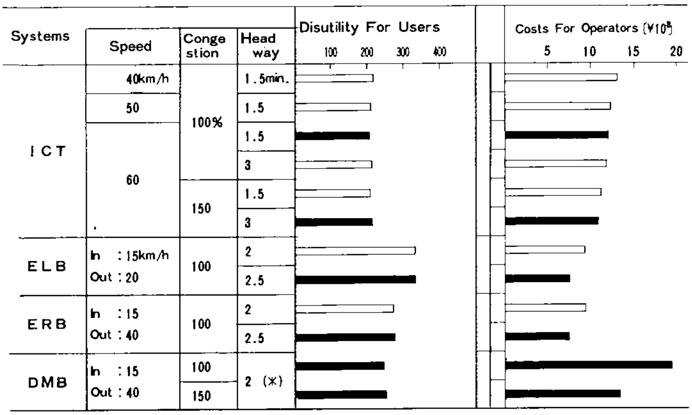
FIG 17

EVALUATIONS OF USERS AND OPERATORS

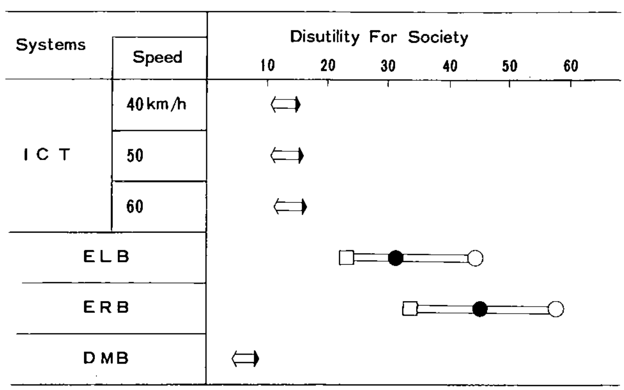


(*) Stop Skipping Service

(23)

FIG 18

EVALUATION OF SOCIETY



Fluctuations Due To Levels Of Noise

Fluctuations Due To Levels Of Exhaust Gas

(○ Present, ● Cut Of 50%, □ Cut Of 80%)

(24)

FIG 19

CHARACTERISTICS OF TRANSPORT SYSTEMS FOR "TRADE-OFF" ANALYSES

Systems	Headway (min)	Congestion (%)	Skipped Stops	Routes	Speed (km/h)	Noise / Air Pollution
ICT (A)	1.5	100	0	1	60	N : High
ICT (B)	3.0	150	0	1	60	N : High
ELB	2.5	100	0	4	20	A : 50%Cut
ERB	2.5	100	0	4	40	A : 50%Cut
DMB (A)	2.0	100	2	4	40	N : High
DMB (B)	2.0	150	1	4	40	N : High

(25)

FIG 20

"TRADE-OFF" BETWEEN USERS AND SOCIETY

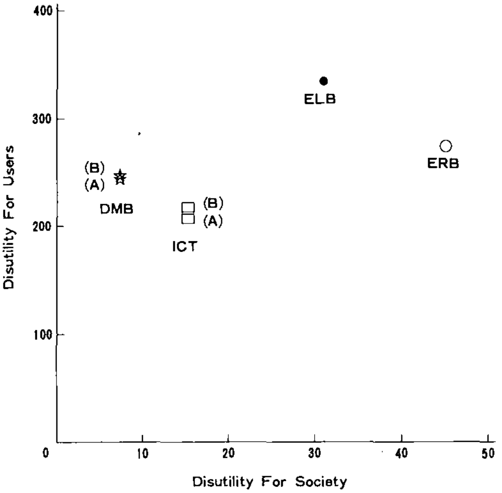


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FIG 21

"TRADE-OFF" BETWEEN USERS AND OPERATORS

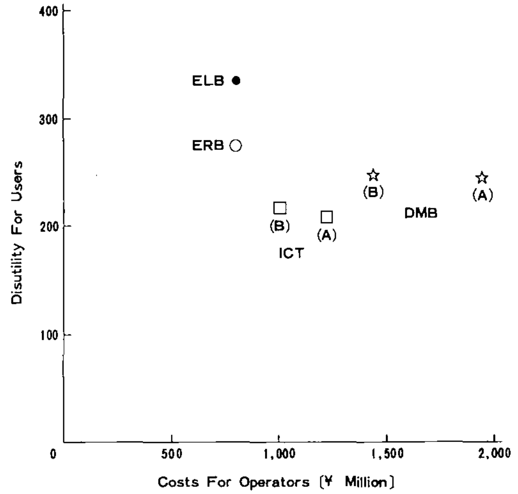

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FIG 22

"TRADE-OFF" BETWEEN SOCIETY AND OPERATORS

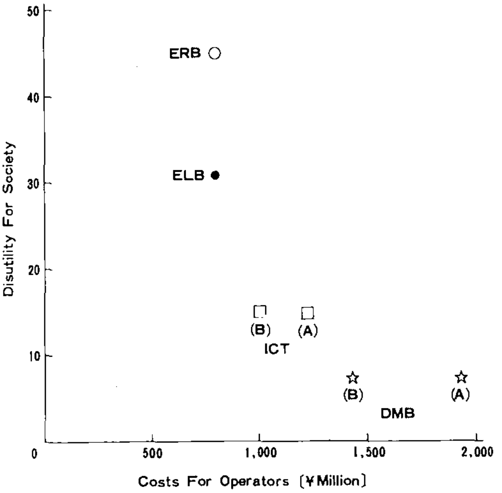

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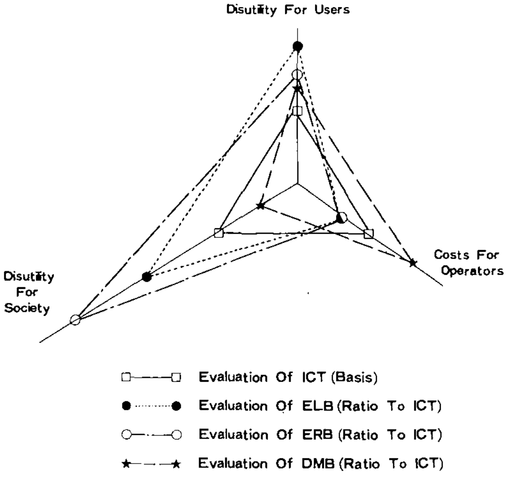
FIG 23

"TRIANGLES" OF EVALUATION OF FOUR SYSTEMS



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