ECONOMIC APPRAISAL OF POLICY ALTERNATIVES OF TRANSPORTATION MANAGEMENT; A CASE STUDY IN FUKUOKA CITY

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abstract: This study aims firstly to propose models to evaluate economic effects of a number of policy alternatives of Transportation Demand Management (TDM). The models are developed by extending so-called Four-step Aggregate Demand Prediction Method commonly used in many local governments in Japan. The effects are calculated based on the saved travel time resulting from a certain alternative of TDM. Secondly, they are applied in the transportation planning process in Fukuoka City, in order to provide evaluative information and to facilitate the discussion among the participants interested in the introduction of TDM.

1. INTRODUCTION

The traditional scheme in tackling traffic congestion in urban areas is to provide new road infrastructure to increase the traffic capacity; for example, construction of a bypass and an overpass. Recently, however, this scheme has met many difficulties. Among them are the increase of construction cost owing to expensive land prices in urban areas, and longer time to make consensus on new road projects as people have become more concerned with their environment. Furthermore, the capacity expansion is questioned fundamentally for the reason that the transportation demand is so large that it might absorb the added capacity instantly, resulting in worse environment without any improvement in congestion.

This is why Transportation Demand Management (TDM) has been highlighted and introduced as a measure to solve the traffic congestion problem. The basic idea of TDM lies in the control of transportation demand itself, whereas in the traditional planning process the demand is a given constraint and remains out of planners' control. TDM is not a fixed method but a set of many alternative ways of control; for example, traffic restraint (area-wide restraint, control based on the car license number), promotion of efficient use of private cars (ride-sharing and exclusive lanes for highly occupied vehicles), transfer of transportation demand from peak period to off-peak one (flextime working system, road pricing).

In the planning and implementation process of TDM, the key is substantial citizen participation or involvement because TDM often requests people to bear some burdens in the forms of traffic regulations and/or new user charges. The success of TDM depends on how clearly people understand the objectives of TDM and its expected benefits as well as the burdens. In order to realize it, therefore, transportation planners should be ready to provide evaluative information on various alternatives of TDM.

This study aims, firstly, to propose models to evaluate economic effects of TDM. The models should be simple and practical in order to facilitate the interactive citizen participation process where people can make some inputs in the proposed alternatives and evaluate their effects in easy terms. This is why the models are developed by extending the so-called Four-step Aggregate Demand Prediction Method commonly used in many local governments in Japan. Secondly the models are applied in the transportation planning process in Fukuoka City, where the congestion has become worse and TDM is believed to be one of the most effective measures.

2. MODELS

2.1 Requirements for the Models

The models are expected to evaluate a number of alternatives of TDM in a common term. So far, several alternatives of TDM have been evaluated independently; for example, the time-saving effect of information on available parking spaces in the Central Business District (CBD), and the demand-transfer by the flextime working. However, these should be evaluated simultaneously using the same evaluative term. In this sense, the desirable term is a "money term", which is familiar and understandable for the participants.

The models should also be interactive enough to input manually the probable impacts on people's behaviors resulting from the introduction of a certain scheme of TDM. Those impacts cannot be predicted systematically but rather obtained after exchanging views among the participants. For instance, it is vague whether the "No Car Day" campaign, which asks people not to use voluntarily their cars on a pre-determined day of month, is effective or not. In this case, we should first suppose the popularity of the scheme and predict the numbers of supporters and the actualized volunteers, through exchanging views and making common knowledge on the likely events following the scheme's introduction. With these numerical inputs, the models can predict its economic effects quantitatively. Thus, the models should be equipped with an interface friendly to the interactive planning.

2.2 Framework of the Models

The framework of the appraisal models is shown in Fig.1, where the main stream indicates the procedure of the Four-step Aggregate Demand Prediction Method (FADP); i.e., trip generation, trip distribution, modal split, and route assignment. As mentioned above, each policy alternative of TDM on the left-hand side is transformed into the policy parameters in the interactive planning process. The role of policy parameters is to clarify the policy alternatives and describe numerically their likely impacts on "transportation demand reduction" or "link capacity utilization".

FADP predicts daily traffic volume by link. For the purpose of evaluating a certain TDM alternative (e.g. ban of peak-hour trucking), we need traffic distribution within a day, during both peak and off-peak periods. Thus, on the right-hand side in Fig.1, "Time distribution model" is added in order to simulate each link's traffic distribution by time of day. "Travel time model" is also developed to estimate average travel time along the links and average waiting time at the intersections. Based on these models, travel speed by link is calculated and then travel time by link by time of day is obtained assuming both situations of "with" and "without" TDM. Finally "Benefit model" transforms the accumulating travel time saved by the introduction of TDM into money-term benefit.

2.3 Adopted Models

2.3.1 Data

The data used in our models are mostly from "Person Trip Survey (PTS) 94" conducted in the northern Kyushu Area. A PTS in Japan investigates people's travel behaviors in a day by destination, purpose, and mode, which provides basic information for transportation planning. In addition, several related surveys were done on parking

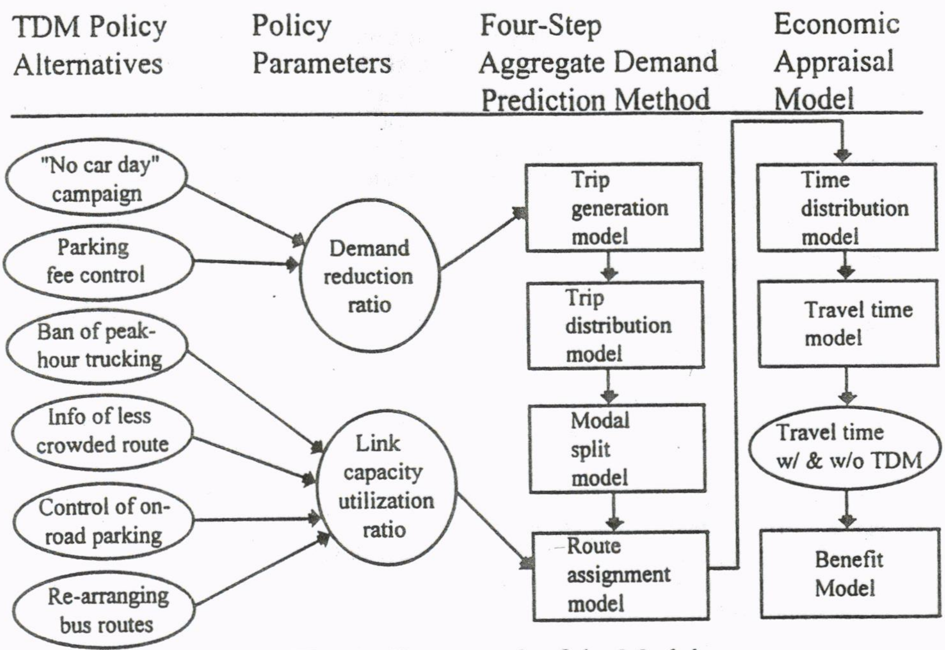

Fig. 1 Framework of the Models

facilities and their fees, intersection waiting time, and traffic information system and its effects.

2.3.2 Trip generation model

The number of trips generated from/to the CBD is determined to alter the existing volume in two ways: "by reducing overall transportation demand" and "by transferring the parking places from the central area to the fringe area".

In the latter case, the generated vehicle trips are obtained by;

$$Vi = Pi \cdot y\,i \quad (1)$$

$$y = A - B \cdot X - C \cdot Z \quad (2)$$

where:

- Vi is the generated vehicle trips in area i,
- Pi is the number of parking lots in area i,
- y, (yi) is the utilization ratio of parking lots (in area i),
- X is the parking fee per hour (yen),
- Z is the distance between the city center and the parking place (m).

Based on the aggregated vehicle trip data by area, the parameters are estimated;

A = 90, B = 0.039, C = 0.025,

(Multi-correlation coefficient is 0.76).

2.3.3 Route assignment model

Route assignment model introduces an algorithm of "Shortest distance method", with supplementary tuning to the existing distribution pattern. One of the policy parameters, link capacity utilization ratio, can work in this model; for example, control of on-road parking makes the parameter larger resulting into improved traffic.

2.3.4 Time distribution model

Time distribution model provides information on traffic distribution of major links by time of day, which can make it possible to evaluate the impacts of TDM on the traffic shift from a peak period to an off-peak period. To avoid operational difficulty, the time distribution is not determined based on hourly traffic simulation, but it is tentatively obtained by breaking down the daily traffic to keep the existing distribution pattern observed and then it is modified by estimating the likely adjustment owing to the introduction of TDM.

2.3.5 Travel time model

Once the hourly traffic is obtained, we can estimate the travel speed by time of day by;

$$Sij = A - B \cdot Vij / Ci \quad (3)$$

$$Ci = \alpha Pi \quad (4)$$

$$Pi = P \cdot \beta 1 \cdot \beta 2 \cdot \beta 3 \cdot \beta 4 \cdot \beta 5 \cdot \beta 6 \quad (5)$$

where:

Sij is the travel speed of link i at the time j (km/h),
Vij is the traffic volume of link i at the time j,
Ci is the traffic capacity of link i with on-road parking,
Pi is the traffic capacity of link i without on-road parking,
P is the standard traffic capacity (2,200 PCU/hour/lane),
α is the traffic reduction ratio owing to on-road parking,
$\beta 1, \beta 2, \beta 3, \beta 4, \beta 5, \beta 6$ are adjusting parameters reflecting lane width, side space, etc..

$\alpha = 0.80$ is independently introduced based on the observation at the intersections.

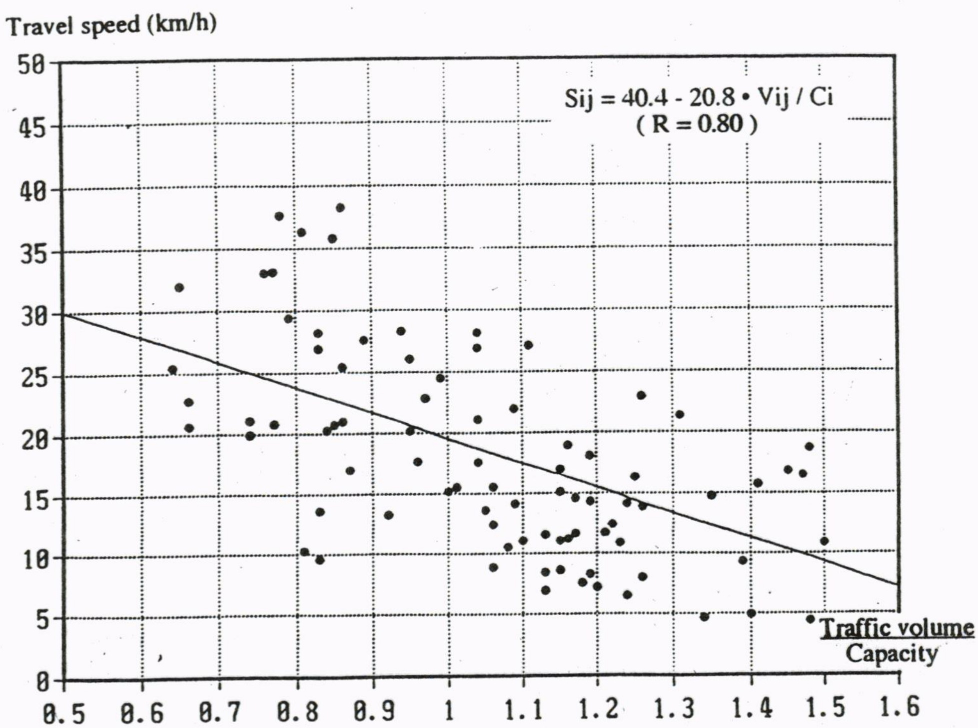

Fig. 2 Hourly traffic volume and travel speed

The parameters, A and B, are obtained through regression analysis using the data in Tenjin (Fig.2) ;

A = 40.4, B = 20.8, (Multi-correlation coefficient is 0.80).

2.3.6 Benefit model

Benefit model estimates the benefit by multiplying the saved time resulting from TDM by unit time value. The adopted model is;

$$T = \sum_i \cdot \sum_j \left(li/Sij - li/S'ij \right) \cdot Vij \text{ , or } \sum_n \cdot \sum_k \cdot \sum_j \left(Cnkj - C'nkj \right) \cdot Wnkj \cdot L \quad (6)$$

$$B = T \cdot v \cdot 365 \quad (7)$$

where the second member of the equation (6) is only applied in evaluating the effects of Re-arranging bus routes on the congestion at the intersections:

T is the total saved time with TDM,
li is the length of link i,
Sij is the travel speed of link i at the time j without TDM,
S'ij is the travel speed of link i at the time j with TDM,
Vij is the traffic volume of link i at the time j,
Cnkj is the congestion rate of lane k of node n at the time j without TDM,
C'nkj is the congestion rate of lane k of node n at the time j with TDM,
Wnkj is the traffic volume of lane k of node n at the time j,
L is the unit loss time in proportion to the congestion rate (140 seconds),
B is the annual benefit,
v is the unit time value.

62 yen/min is introduced as the unit time value, which is calculated by;

$$v = (\text{average income}) \cdot (\text{no. of passengers}) / (\text{annual working hours}). \quad (8)$$

3. CASE STUDY

In Fukuoka City, about 1,000 km west of Tokyo, TDM is evaluated as a scheme to relieve the traffic congestion in the CBD named Tenjin, having an area of 71 ha and more than 4,100 business establishments. Although Tenjin area has many links and nodes, we concentrate our attention to the most crowded 13 links of 5 major trunk roads and 4 nodes or intersections, on which our model is applied to estimate the travel time.

3.1 Policy Alternatives in Fukuoka City and Their Benefits

3.1.1 "No car day" campaign

"No car day" campaign targets both private and commercial cars. However people cannot refrain from commuting by car if they do not have an alternative mode, nor can the commercial firms cease from transporting freight by car if they have no choice. During the discussion it seems more feasible to ask private firms not to allow their employees to use their commercial cars for commuting purpose. According to the result of questionnaire on "Car ownership and usage", 20.5 % of cars owned by private firms in Tenjin are used for commuting purpose as well as commercial purpose. In our calculation, if such usage is not allowed, 6.0 % of trips can be reduced .

Another possibility is that a proportion of commercial trips by car can shift to other modes, considering that 3.0 % of trips are made for a commercial purpose without freight transport. Furthermore, the campaign could reduce to some extent the trips by private cars used for shopping or other purposes.

Based on these discussions, it can be concluded that "No car day" campaign could reduce at least 5 % of transportation demand. Although "No car day" campaign is being conducted on a pre-determined day of month now, it is assumed that the moderate 5 % can be achieved every working day of week. A 5 % reduction increases the travel speed by 1.3 km/h to 23.1 km/h, and 502 million yen benefit annually (Table 1).

Table 1 Effects of "No car day" campaign

Demand reduction	Average speed (km/h)	Saved time (hours/day)	Benefit (mil yen/year)
existing demand	21.8	---	---
5% reduction	23.1	370	502
10% reduction	24.2	622	845
15% reduction	25.4	845	1,147

3.1.2 Parking fee control

In order to facilitate parking at the fringe area instead of parking at the central area, a TDM alternative of parking fee control is examined. During the discussion, the discount of parking fee in the fringe area is preferred over the increase in the central area. Several discount rates are analyzed concerning their sensitivity on the trip generation (Table 2). Based on this analysis, a 10 % discount of parking fee at the fringe area, which is considered as the most feasible alternative, is estimated to have 116 million yen benefit annually (Table 3).

Table 2 Trip reduction in the central area by parking fee control

Parking fee at fringe area	Trips to/from the central area (trip ends/day)	Reduction rate (%)
existing rate	126,821	---
10% discount	125,004	1.4
20% discount	123,084	2.9
30% discount	121,621	4.1

Table 3 Effects of parking fee control

Parking fee	Average speed (km/h)	Saved time (hours/day)	Benefit (mil yen/year)
existing rate	21.8	---	---
10% discount	22.1	86	116
20% discount	22.4	170	231
30% discount	22.5	221	287

3.1.3 Ban of peak-hour trucking

Ban of peak-hour trucking was strongly opposed by trucking firms and shippers in Tenjin. This is partly because Tenjin has introduced an area-wide inter-carrier freight consolidation system for more than 15 years. In the consolidation system all cargoes from/to Tenjin are required to be transported by the newly established cooperative trucking firm, resulting in traffic reduction. At the same time, however, it causes inconvenience to the shippers to some extent; e.g. unsatisfactory just-in-time requirement. Therefore it was decided not to investigate the feasibility of this unpopular scheme, but to provide reference information on the possible effects, assuming that the traffic of the concerned links by time are leveled by restricting the movement of trucks at a peak period. With this extreme assumption, however, the annual benefit is only 352 million yen (Table 4).

Table 4 Possible effects of leveling traffic by time

	Average speed (km/h)	Saved time (hours/day)	Benefit (mil yen/year)
existing pattern	21.8	---	---
leveled pattern (an extreme case)	22.6	259	352

3.1.4 Information on less crowded route

In theory, informing the less crowded route is very efficient way to utilize the existing capacity by leveling traffic volume between crowded and less crowded links. However, the potential benefit of this alternative route information scheme as well as the details of its implementation is still big questions.

In the discussion, rather skeptical opinions were aired, saying that most road users know daily crowded pattern, or that the drivers of taxis (35 % of the traffic in Tenjin) and trucks (27 %) already use a wireless communication system to get such information and an additional system would bring little benefit. Thus, again, further development of this scheme proved unprofitable. However, the possible effects are estimated, assuming that the traffic of related links are leveled as much as possible. The results are shown in Table 5, where the leveled pattern is expected to bring 724 million annual benefit at the most.

Table 5 Possible effects of leveling traffic by link

	Average speed (km/h)	Saved time (hours/day)	Benefit (mil yen/year)
existing pattern	21.8	---	---
leveled pattern (an extreme case)	23.7	533	724

Fig.3 shows the ideal situation of leveling traffic by link. In Fukuoka there are two trunk roads, Showa-line (8 lanes) and Kokutai-line (4 lanes), which run through the CBD from the east to the west. At present Showa-line is relatively less congested than Kokutai-line. We estimated the benefit of TDM by shifting the traffic along Kokutai-line to Showa-line so as to keep the same congestion rate.

3.1.5 Control of on-road parking

Although on-road parking is prohibited along major roads in Tenjin, there often occur many violations. The participants share a view that strict enforcement by the police and traffic wardens is a quick remedy for the congestion. Furthermore, an experimental enforcement system along a road in Tenjin shows very good performance. In this system, the illegal parking is monitored by the remote-controlled TV and the drivers are immediately cautioned through a loudspeaker by the officer in the traffic center. This method can get rid of illegal parking dramatically. The benefits of removing all on-road parking is estimated to be 235 million yen annually (Table 6).

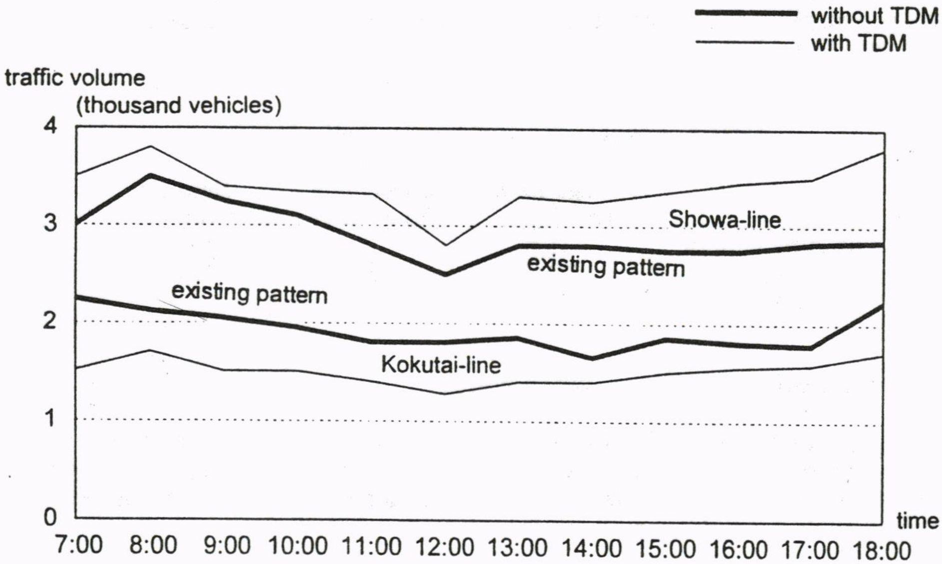

Fig. 3 Leveling traffic by link

Table 6 Effects of control of on-road parking

	Average speed (km/h)	Saved time (hours/day)	Benefit (mil yen/year)
with illegal parking	21.8	---	---
without parking	22.4	172	235

3.1.6 Re-arranging bus routes

Many bus lines in Fukuoka City have their starting/ending points in Tenjin, so that bus traffic largely contributes to the congestion there. The discussion focused on the right-turns of buses at the major intersections, which often become obstacles in left-hand traffic. Thus we investigated the feasibility of re-arranging bus routes and its effects. It is found that re-arrangement of certain routes is not easy to achieve, so that the effects were estimated based on the assumption that as many as 30 % of right-turns are changed to go-straights or left-turns. The re-arrangement at three major intersections in Tenjin makes 99 million benefit annually (Table 7).

Table 7 Effects of re-arranging bus routes

Intersection	Congestion rate (without change)	Congestion rate (with change)	Saved time (hours/day)	Benefit (mil yen)
Hasiguchi	0.871	0.865	16.9	23
Tenjin	0.881	0.873	17.1	23
4-chome	0.891	0.795	39.3	53
total			73.3	99

3.2 Evaluation of TDM Alternatives

Overall evaluation of TDM alternatives is made in Table 8. It should be noted that the benefits of 2 alternatives, Ban of peak-hour trucking and Information on less crowded route, are estimated assuming extreme or ideal conditions with maximum effects. Concerning other six alternatives, the most feasible ways to implement them were tackled.

Table 8 Evaluation of alternatives

Alternative	Feasible implementation	Benefit	Evaluation
"No car day" campaign	5% reduction	502	excellent
Parking fee control	10% discount	116	fair
Ban of peak-hour trucking	(at most)	(352)	---
Info on less crowded route	(at most)	(724)	---
Control of on-road parking	no on-road parking	235	good
Re-arranging bus routes	30% re-routing	99	fair

In the comparison, the "No car day" campaign gets the highest score, 502 points, despite the moderately assumed traffic reduction rate of 5%. The Control of on-road parking comes second, having 235 points. This benefit is calculated assuming strictly that there is no illegal parking, taking into account the successful implementation of TV monitored enforcement system. On the other hand, the Parking fee control and Re-arranging bus route are graded as "fair" with moderate benefits.

In the decision making process, we provided this result. However we did not intend to choose one alternative among the six alternatives, which are not exclusive one another. Rather we persuaded the participants that the above alternatives except Ban of peak-hour trucking and Information on less crowded route had a certain benefit involving different interest groups, and that all related groups had to make some efforts jointly in order to realize the promised benefits. Re-arranging bus routes, for instance, is ranked "fair" with 99 points, but the promised benefit is sufficient enough to ask the bus company to make some efforts.

4. CONCLUSION

It can be concluded that the proposed models are proven to be useful and practical in providing evaluative information on TDM alternatives for the participants involved in the transportation planning process. The key in the development of models is introducing simple evaluation framework without complicated feedback relations and utilizing commonly used methods, which make it possible to reflect people's opinions in the interactive process.

In the case study, it was proved that the "No car day" campaign was the most beneficial among the TDM alternatives, and that the Control of on-road parking also had good performance. This finding depended on the participants in the particular planning process in Fukuoka City, so that it is not generally applicable to other cities.

There remain many sub-models or parts which should be improved. For one, there is a need to develop a simple method to simulate congestion at the intersections which is consistent with the method to simulate links' traffic. In our model, each pair of origin and destination's travel time is calculated to sum up the travel time along the related links, and in the case of evaluating Re-arranging bus routes the travel time at the related intersections is separately estimated. Although it was believed to be inefficient that the intersection traffic phenomenon was simulated independently of the links' one, we should reconsider it in order to meet the research requirement on TDM alternatives with the advantage of the increasing calculating capability.

Another concern is the implementation cost of TDM. In Fukuoka's case, the implementation cost of TDM is not considered and only the benefits of the alternatives are compared, to make the problem simple. In other words we set a limit to the area of alternatives, which do not require much cost.. In general situation, however, not only TDM schemes but also other policy alternatives, some of which are costly, should be evaluated at the same time. For this sake, we should develop more comprehensive method to compare both cost and benefit.

ACKNOWLEDGMENTS

The author would like to thank Mr. Ikushi Yamashita (Sanei Planning Inc.) for providing data and giving valuable comments.

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