MOTORIZATION AND ROLE OF MASS RAPID TRANSIT IN EAST ASIAN MEGACITIES*

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This paper attempts to explore factors influencing car ownership and car use rates. Through regression analysis, the effects of common urban transport policy measures on car ownership and car use rates are estimated. In addition, dynamics of the urban transport system through feedback loops diagram is examined at the macro-level. Our analysis suggests that common policy measures intended to control motorization are effective through their effects more on car use rate than on car ownership rate. Likewise, Mass Rapid Transit (MRT) can play a significant role in improving overall condition of urban transport. However, the impact of MRT would be insignificant if the investment is committed too late. A simple index for MRT timing has been proposed that could help policy makers from cities without MRT systems to make judgments about the appropriate timing of MRT investment. Regression results, feedback loops diagram and proposed index for MRT timing offer new insights for formulating policy measures for sustainable urban transport in East Asian megacities.

Key Words: Urban transport, Motorization, Mass rapid transit, East Asia, Megacities

1. INTRODUCTION

Rapid urbanization coupled with higher economic growth in East Asian megacities is creating a perfect condition for an explosive trend of motorization. Inadequate urban road networks in these megacities is already under severe pressure as reflected by the worsening condition of traffic congestion. The growth rate in road expansion is lagging far behind that of motor vehicles. Traffic gridlock especially during peak-hour has been a rule rather than the exception in major arterial routes. Various policy options are under discussion and some are even under implementation but the traffic congestion trend is yet to see any degree of reversal in most Asian megacities[1]. With such a background, this paper explores the policy measures for managing motorization. In particular, the role of Mass Rapid Transit (MRT) is examined and a simple index is proposed to help decision makers to make judgments about the timing of MRT investment. The contents of the paper include parts of outputs and insights from an international collaborative research study titled "Sustainable Transport for East Asian Megacities (STREAM)".

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The next section presents trends of motorization in the form of increasing ownership and use of private vehicles namely cars and motorcycles in selected East Asian megacities. This will be followed by a discussion on key factors influencing car ownership rate and car usage rate including a regression analysis to examine the effectiveness of some commonly discussed policy options. Next, the dynamics of urban transport system is discussed to identify key underlying mechanisms and to draw policy implications for East Asian megacities. This will be followed by a discussion on timing of MRT investment including the proposition of a simple timing index. Finally, the conclusion is presented.

2. MOTORIZATION TREND

Figure 1 shows the trends of car ownership in selected East Asian megacities over the 1980-2004 period. The car ownership trend in Tokyo prefecture of Japan appears to be quite restrained given the higher income level of Tokyo. The car ownership rate in Seoul and Taipei witnessed a rapid rise from the mid-1980s, whereas Bangkok and Jakarta experienced a steep rise in the 1990s. The trends for some cities also show that the car ownership ratio dropped down for the same period during the

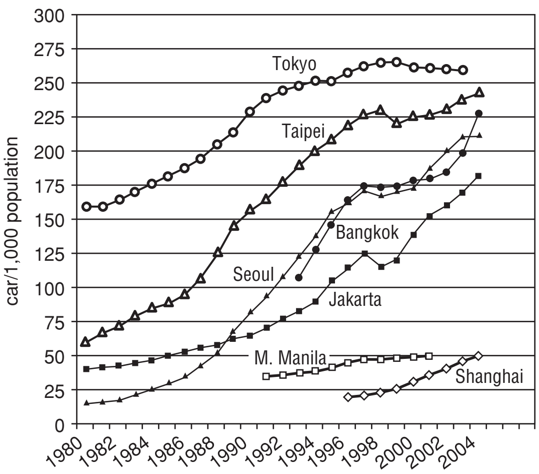
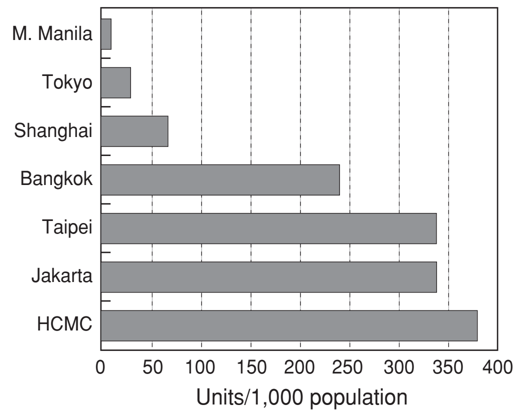


Fig. 1 Car ownership trend



Source: STREAM study, 2006

Fig. 2 Motorcycle ownership 2004

late 1990s apparently due to Asian financial crisis. However, after recovery, the growth rate has already picked up. With such trend, the car ownership rate in developing megacities of East Asia may reach that in automobile oriented cities of USA.

Most East Asian megacities are facing rapid growth not only in car ownership level but also in usage of cars. Annual vehicle-km per car unit for Tokyo is 8,850 km while the figures for Taipei, Seoul, Manila, and Beijing are 10350 km, 16013 km, 11509 km and 18300 km respectively. Only Jakarta and Bangkok have figures below that of Tokyo as 7160 km and 6126 km respectively[2]. As the process of suburbanization is gradually speeding up in most of these megacities, the figure for vehicle-km per car is likely to increase in the future. Motorization is therefore advancing in terms of both increases in car ownership rate and car usage rate.

Another specific aspect of motorization in Asian megacities is the higher level of motorcycle ownership and use (Fig. 2). Many complementary factors seem to be at work to produce such a high degree of motorcycle use in the region. First, the low price of motorcycles (as compared with cars) allows a growing middle class population to own their private vehicles. Second, the need of motorcycle use is further intensified due to the poor quality of public transport. Third, in cities like Bangkok and Jakarta, the inappropriate road hierarchy (missing secondary roads) allows only motorcycles to access inner neighborhood. Finally, motorcycles allow the rider to weave through the congested traffic- a common feature of roads in East Asian megacities. With such a context, we can see that the motorcycle is likely to remain as a dominant mode in the future refuting the common assumption that the higher level of motorcycle use is just a transient trend when income is relatively lower and public transport is poor. This is well demonstrated by the case of Taipei where higher use of motorcycles remains in place despite higher levels of income. The motorcycle issue thus creates a special kind of complexity in managing motorization in East Asian megacities.

3. FACTORS INFLUENCING THE MOTORIZATION

3.1 Stylized facts

The key factor driving the motorization trend is the level of per capita income. Literature on car ownership suggests per capita income of $5,000 as the threshold at which car ownership begins to take-off[3]. Because of increasing trend of domestic production of cars, a more realistic threshold income should be expressed in terms of purchasing-power parity (PPP); *The Economist* suggests a threshold of $6,000 measured by PPP terms[4]. Per capita income in Bangkok is already above this threshold level and that in other megacities such as Beijing, Shanghai, Jakarta and Metro Manila, is very close to this threshold or approaching soon. This shows that East Asian megacities are potentially subject to a rapid growth in car ownership.

Figure 3 (left panel) plots car ownership rate against the metropolitan income using metropolitan level cross sectional data (only metropolitan areas with populations of more than 2 million are included) of the year 1995 compiled by UITP showing strong positive correlation[2]. However, there is a significant difference in car ownership rate between US-Australian cities and developed Asian cities. The developed Asian cities stand out clearly

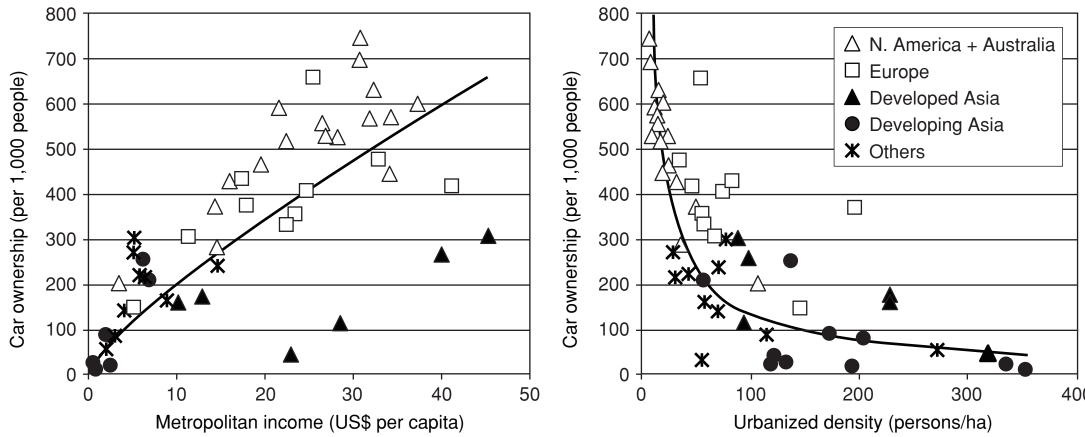


Fig. 3 Car ownership rate with respect to income level and urban density

as cities with lower car ownership rates. There is also wide variation within the developing Asian cities; some showing quite high levels of car ownership even at the lower level of income. The right panel of Figure 3 partially explains a possible cause for the variation of car ownership across the cities. The panel shows that higher population density in a city results in lower car ownership rate than otherwise would have occurred. The urban density, in fact, may influence car ownership through different ways, such as through its positive effect on accessibility and diminished need of car ownership or negative effect on congestion and disincentive for car ownership.

Using the same data set, key factors that determine car use rate are also explored. It was found that average road speed has a stronger effect on car use rate, which is illustrated by the left-panel of Figure 4. There is also significant variance in the car use rates in cities with similar levels of road speed. Here too, urban density partly explains the variations showing that higher urban density discourages car use, which is simply in line with intuitive conjecture.

There are other complementary factors contributing to the rapid growth of car ownership in these megacities. These include, first, the government policies to promote the automobile industry as one of the core elements of growth strategy. For example, the Chinese government in 1994 formulated an industrial policy recognizing the automobile industry as a pillar industry of the economy. Similar strategy (if not the same level of emphasis) can be traced also in other countries. Such deliberate government policy made it possible to drastically increase the domestic production of automobiles even in developing countries in a relatively short span of time. China, Thailand and Indonesia produced 1.55, 0.34 and 0.21 million units of light vehicles respectively in 1997; by 2005 the production figures jumped to 5.1, 1.1 and

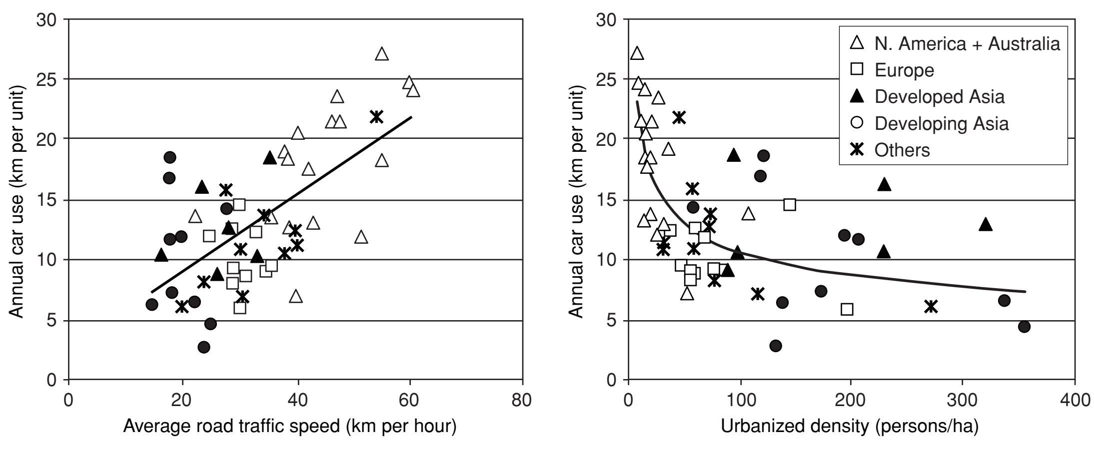


Fig. 4 Car use rate with respect to road speed and urban density

0.48 million units respectively[5]. The domestic production drastically reduces the price of cars. The requirement of international trade regimes to cut import duty and other taxes also contributes to price cuts. In addition, government policy also encouraged finance institutions to provide consumer loans for car purchase. China reversed such policy of easy consumer credit in 2004 only after it created a series of defaults on vehicle loans in 2003[6]. All these factors make car purchase affordable for the large and expanding middle class population.

In most developing countries, the perception of middle class population that symbolizes car ownership with social status, individual freedom and personal success is further intensifying the motorization drive. In fact, given the inefficient condition of public transport in most of these megacities, people may find it a rational decision to own a car as a mode of desirable service quality. All these factors when they act in combination create a powerful synergy to drive the car ownership trend with unprecedented speed as currently visible in most of the East Asian megacities. For example, Beijing took 48 years to accumulate the first million automobiles in 1997, but only six years for the second million and the third million is to come by 2008[7].

3.2 Regression analysis

The factors discussed above, in fact, do not constitute an exhaustive list of factors determining the level of motorization. Other important and potentially significant factors may include those related to the availability of cars, cost of car use, and cost and service level of public transport. Regression analyses are conducted to examine the effect of all these factors on motorization. The above-mentioned metropolitan level cross-sectional database compiled by UITP is utilized for the purpose[2]. As discussed above, car ownership rate and car usage rate are chosen as the proxies of motorization, and regressed against independent variables representing factors that are likely to influence the process of motorization. These factors include income level, urban density, service level of road transport, availability and service level of public transport, and user's costs. List of the cities, descriptive statistics and correlation matrix are given in the annex. Regression results are shown in Table 1.

Car ownership rate (CW) is first regressed against a set of independent variables (Model-1 in Table 1) representing major factors that may have effects on the ownership rate. As expected, urban density (UD) and income level (INC) have negative and positive correlations respectively on car ownership rate (CW). Both variables take statistically significant parameters, which implies that higher urban density discourages car ownership while higher income increases car ownership rate. Average speed of road traffic (RDS) is picked up as an independent variable to represent the service level of road networks. RDS takes a positive parameter but the effect on car ownership is not statistically significant. Likewise, the user's cost for private mode (UCC) takes an expected negative sign but the effect is not significant. The size of heavy rail network (RLN) and number of buses in operation (BUS) are chosen to represent availability and service level of public transport services. RLN has a significant effect implying that provision of a dense urban rail network may discourage car ownership rate. However, BUS failed to record a statistically significant effect on car ownership, though it takes an expected negative sign. The model explains 77 % variation in the dependent variable as shown by R^2 value.

Model-2 drops some variables from and adds few others to Model-1 in order to test new variables avoiding possible multicoliniarity. Urban density (UD) retains its negative sign with stronger effect apparently soaking part of the effect of income (INC). As a representative of overall public transport, the variable named public transport route length (PT) is added, but the effect is not statistically significant. For parking space in CBD (PRK), and user's cost difference (user's cost of private mode minus user's cost of public mode) between private and public modes (UCD), both of them common policy instruments often discussed in practice, the parameters are not statistically significant. These results cast a doubt on the effectiveness of such measures in controlling car ownership rate. Differences in average speed of private and public modes (SPD), takes positive and statistically significant parameters implying that differences in service level of private and public mode matters for car ownership decision.

In model Model-3 and Model-4 car use rate (CU) is regressed against the same groups of independent variable as in Model-1 and Model-2 respectively. Keeping the same group of independent variables, it is possible to compare the effects of each on car ownership rate and car use rate which may produce interesting implications for practical policy making.

As shown in Model-3 of Table 1, urban density (UD) fails to be statistically significant, apparently due to multicolliniarity with income (INC). Average road speed (RDS) and user's cost for private mode (UCC) both record statistically significant parameters with expected signs, while these variables do not have significant effects

Table 1 Regression results for car ownership and car use rate

	Dependent variables			
	Car ownership rate (CW)		Car use rate (CU)	
	Model-1	Model-2	Model-3	Model-4
Const	141 (85)*	317 (55)**	9476 (3373)**	14439 (1649)**
UD	−0.66 (0.22)**	−1.36 (0.27)**	−4.80 (8.88)	−19.07 (7.95)**
INC	0.012 (0.002)**		0.205 (0.080)**	
RDS	2.88 (1.96)		169.5 (78.2)**	
UCC	−149 (131)		−15118 (5221)**	
RLN	−0.10 (0.03)**		−2.80 (1.38)**	
BUS	−0.0002 (0.030)		−0.7037 (1.185)	
PRK		0.078 (0.07)		3.62 (2.07)*
PT		0.0029 (0.0045)		−0.2247 (0.1343)*
UCD		264.28 (177)		−6994.04 (5269)
SPD		4.07 (2.5)*		142.05 (74.1)*
R2	0.77	0.53	0.5	0.43
No of obs	54	54	54	54

Numbers in parentheses are standard errors
** Significant at 5 % confidence level
* Significant at 10 % confidence level

Definition of variables and unit of measure	
CW	Car ownership rate (no of car per 1000 population)
CU	Annual car usage rate (Km/unit)
UD	Urban density (person per hacter of urbanized area)
INC	Metropolitan income per capita (US$/capita)
RDS	Average speed of road traffic (km/hour)
UCC	User's cost for private mode (US$/pass-km)
RLN	Heavy urban rail network (Km)
BUS	No of buses in operation (units/million people)
PRK	Parking space in CBD (parking units per 1000 CBD jobs)
PT	Public transport route length (meter per 1000 people)
UCD	Difference of user's cost for private and public mode (US$/pass-km)
SPD	Difference in average speed of private and public modes (km/hr)

on car ownership rate. BUS does not have significant effect on car use rate, but the size of urban rail network (RLN) shows strong negative effect also on car use rate (as in the case of car ownership). This result is in contrary with the result of some more rigorous causal analysis[8]. However, in developing countries, since the policy goal is to retain the existing high mode share of public transport rather than modal shift from cars, significant impact of urban rail on car use rate is understandable.

In Model-4, urban density has significant effects. In addition, parking space in CBD (PRK) and public transport route length (PT), which were not significant for car ownership, are significant with expected signs. As in the case of Model-2, difference in user's cost of private and public mode (UCD) is not significant but difference in average speed of private and public mode (SPD) is significant.

Most of the results in these regressions are simply intuitive. Yet, there are some insightful results; such as the absolute or relative user's cost of private mode do not have significant effects on car ownership. Likewise, it is not the overall coverage of public transport service that discourages car ownership; rather it is the size of urban rail network (a proxy for high quality and high-speed public transport mode) that has stronger negative effect on car ownership. The higher cost of private mode controls motorization through its effects more on car use rate than on car ownership rate. However, lowering the user's cost of public transport may not produce any significant effect on car ownership or car use rate. Only provision of good urban rail network can discourage both car ownership and use rates, and dampen the speed of motorization. However, as is the case with all regression analyses, the results are only indicative and need to be interpreted with caution.

4. URBAN TRANSPORT DYNAMICS AND MASS RAPID TRANSIT (MRT)

4.1 Urban transport dynamics

The regression analysis conducted over the cross-sectional data basically presents a static picture. However, urban transport system constitutes a composite system, which includes multiple subsystems with feedbacks producing complex dynamics. The process of motorization needs to be examined in the context of such complex dynamics of urban transport systems. Figure 5 presents the key components of urban transport systems and feedback links among them, which are widely discussed in the literature[9]. The system structure is aggregated at a broad macro-level, yet it is helpful in understanding the underlying dynamics that are responsible for urban transport problems in growing Asian megacities.

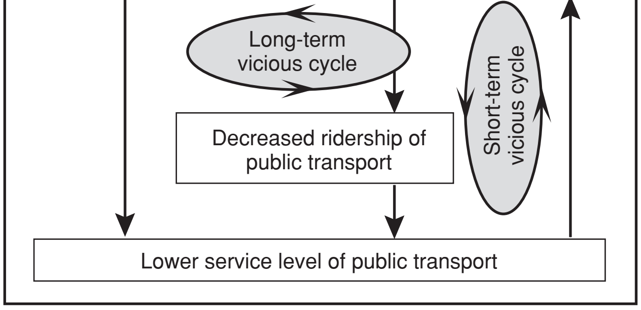


Fig. 5 Key components of urban transport system

As shown in Figure 5, the three main components of urban transport system are use of private automobiles, use of public transport and urbanized density. Most of the urban transport problems are the outcomes of the dynamic interaction among these components. In developing megacities, this system is running through two powerful vicious cycles. First, the increased use of private automobiles immediately causes a corresponding decrease in public transport ridership, which, in turn, lowers the service level of public transport (due to scale effects). Worsening condition of public transport further encourages car use completing a vicious cycle that reinforces the process of increased car use and decreased public transport ridership. This cycle usually gets triggered by income growth with simultaneous effects of increased affordability of cars and demand for higher quality services for public transport causing modal shift from public to private mode. As the effects come relatively in a short-term, the vicious cycle here is termed as short-term vicious cycle. The other vicious cycle comes into play with longer-tem effects of increased car use. Increased use of private mode encourages low-density urbanization as people have more freedom for location choice. Such relation between car use and urban density is supported by empirical data as demonstrated in Figure 4 (right-panel). However, low-density urbanization cannot be served well by public transport, and this causes service quality of public transport to degrade further (not because of operational inefficiency rather because of inappropriate land-use structure) which feedbacks to increased car use.

The short-run vicious cycle may be considered as triggered by "behavioral factors" and the long-run vicious cycle may be considered as triggered and perpetuated by "structural factors". In this case, users' skewed preference (after controlling all relevant mode choice variables) for private mode can be taken as a behavioral factor. Such an unexplained preference for private mode is common especially among the burgeoning middle class population in developing countries, who treat private car more as a status symbol than as a transport means. On the other hand, the low-density urbanization that produce car oriented urban structure making people captive to car use can be taken as a structural factor. Making distinction between such structural and behavioral factors, in fact, has important implications for urban transport policy in developing megacities. Since the structure- both hardware and software- of urban transport system in developing megacities is still in an evolving phase (unlike their counterparts in developed world), there is good scope of achieving a more efficient system structure and thereby avoiding more powerful long-run vicious cycle.

The vicious cycles discussed above are reinforcing feedback loops producing negative effects. However, the same reinforcing loops can also run as virtuous cycle producing positive effects. For example, higher service level of public transport attracts potential car users and increases public transport ridership, which may lead to further service improvement. The challenge here is therefore to turn all vicious cycles into virtuous cycles through various policy measures targeting both structural factors and behavioral factors.

4.2 Implications for urban transport in East Asian megacities

The urban transport dynamics, regression results and motorization trends discussed above when combined together suggest serious implications for urban transport systems in East Asian megacities. As mentioned before, the reinforcing feedback loops shown in Figure 5 run as vicious cycles for these megacities, and the impending surge of motorization to be fueled primarily by economic growth and supported by other policy or non-policy factors would only strengthen and accelerate these vicious cycles. A system dominated by reinforcing feedback process is vulnerable to path dependence[10]. In the case of East Asian megacities, path dependence could mean urban transport systems under a risk of being locked-in for private mode. In other words, if the system is left to run on its own without any major policy intervention (which is effective enough to turn vicious cycles into virtuous cycles), the condition of public transport systems further degrades and over the time, the mode share of public transport hits rock bottom.

Figure 6 illustrates the problem pattern as a result of the above discussed dynamics in East Asian megacities[11]. Most developing East Asian megacities currently have higher public transport ridership. The desirable trend for public transport would be about maintaining such higher levels of public transport ridership. However, in the face of vicious cycles discussed in the earlier section, the do-nothing trend (or business-as-usual trend) would bring the public transport ridership to the much-reduced level. As indicated by the regression analysis, one of the key policy instruments for sustaining public

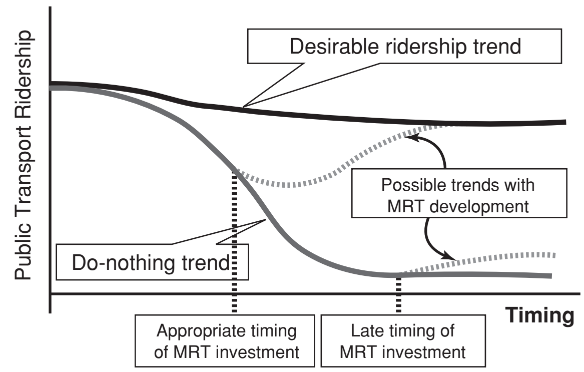
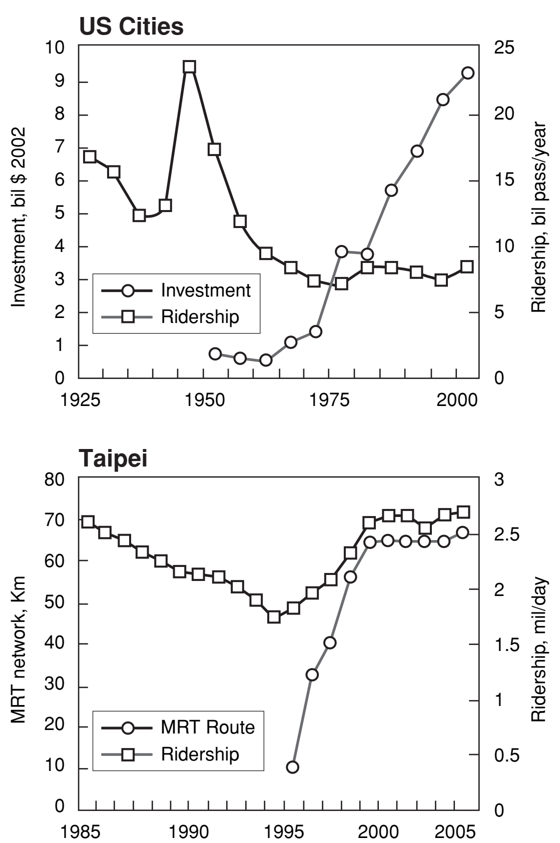


Fig. 6 Timing of MRT investment

transport ridership (or managing motorization) is the investment for Mass Rapid Transit (MRT). MRT can significantly improve the service level of public transport system and may help in breaking down both vicious cycles discussed above. In particular, development of MRT network may even turn the vicious cycles into virtuous cycles through its significant impact on land-use (supporting high-density urban development). However, the option of MRT investment is capital intensive and realizing it too early may not be financially feasible for developing megacities. Figure 6 hypothesizes two possible outcomes of MRT investment. First, if the MRT investment is committed too late, there will be only little gain (practically insignificant) in public transport ridership. When the long-run vicious cycle (increased car use, low-density urbanization and declining service level of public transport) is at work for a relatively extended period, the urban transport structure (including land-use patterns) will not be favorable for public transport. The low-density urbanization will make it almost impossible even for a well-developed MRT system to maintain higher ridership. On the other hand, if MRT investment is not too late, (when urban density is still higher and car ownership rate is relatively lower) it can break the vicious cycle and significantly improve public transport ridership leading to the desirable trend as shown in Figure 6. Here, the timing can be represented through some relevant indicators such as income level, car ownership rate or urban density. Hence, the question is about identifying some critical stage as shown in Figure 6 before which the urban rail system needs to be developed if a megacities want to dampen the otherwise rocketing speed of motorization.

4.3 Empirical test of timing hypothesis

In order to test the patterns hypothesized in Figure 6, historical data on transit investment and ridership for the USA (covering all urban areas) and Taipei are plotted as shown in Figure 7. Interestingly the hypothetical pattern drawn (Fig. 6) based on feedback diagram (Fig. 5) is broadly verified by the empirical patterns from US cities and Taipei. As illustrated by figure 7 (top panel), in the US priority to transit investment came only since the late 1970s[12]. By then the transit ridership was reduced to a very low level. As a policy response, transit investment was gradually increased and by 2000, annual public capital investment for transit was over 9 billion US$. However, the improvement in transit ridership is very marginal. The case of US cities, thus, confirms the hypothesis that if transit investment comes too late, it cannot contribute much to increase transit ridership. The bottom panel of Figure 7 illustrates the MRT development and transit ridership patterns in the city of Taipei. As in the case of US cities, Taipei also faced declining transit ridership, but there was rapid expansion of MRT routes before the ridership was too low. As a result, MRT investment was able to increase ridership significantly. Hence, not-too-late MRT investment helped to regain the ridership in Taipei.



Source: STREAM Study compilation, Altsuler (2003)

Fig. 7 Transit investment and ridership

4.4 Towards formulating timing indicator for MRT investment

In practical policy decision, the common analytical approach to decide on MRT investment is based on conventional framework of Cost-Benefit Analysis (CBA). Extension of CBA framework is sometimes utilized to judge on the timing of MRT investment[13]. However, CBA framework cannot appropriately take account of the important dynamic effects that are dependent on timing of investment as discussed above. Because of associated complex dynamic feedbacks, the analytical formulation to determine the optimal timing of MRT investment is overly demanding in terms of analytical complexity. However, since there are many cities worldwide with MRT systems, the cross sectional data can offer an alternative way to workout some kind of timing indicator based on empirical patterns.

Although there could be a range of relevant variable to judge the timing of MRT, for practical purpose only two key variables are considered- population size of the city and country's per capita income level (at the time of MRT opening). In case of single variable, the average value could give indication about the timing. Since there are two variables, the index is computed taking the geometric mean of normalized (by respective average) value of each variable. The proposed index is termed as Income-Population Normalized Index.

$$IPN.Index = \sqrt{\frac{Income}{Average.Income} \bullet \frac{Population}{Average.Population}}$$

IPN Index taking value of one indicates just average time (we can call it right timing based on empirical pattern); a value less than one indicates early opening while that more than one indicates late opening of subway. To workout IPN Index, data for population and GDP per capita income in the year of subway opening for 46 cities with MRT system (subway) were compiled. Since the data for most advanced cities involved historical data, population and year of subway opening data were compiled by the authors through internet and other sources. GDP per capita in Purchasing Power Parity (PPP) dollars data is from an OECD publication, which provides long-term historical data on GDP per capita[14]. The historical data yields an average population to warrant a subway system as 2.8 million and average GDP per capita as 6202 PPP 1990 dollars. The average GDP per capita is very close to the level of income *The Economist* suggested for take-off of the car ownership rate[4]. The average figure is therefore practically reasonable, as one of key objectives of subway development is to discourage use of

Table 2 IPN Index for selected cities with subway system

	Year of subway opening	GDP per capita (PPP 1990 $)	Population (thousands)	IPN Index	Timing
Tokyo-1*	1927	1,870	3,100	0.57	Early
Paris	1900	2,876	2,714	0.67	Early
London	1863	2,881	2,803	0.68	Early
Toronto	1954	7,699	1,365	0.77	Appropriate
Tokyo-2**	1954	2,582	6,700	0.99	Appropriate
Cairo	1987	2,465	8,326	1.08	Appropriate
Seoul	1974	3,015	6,808	1.08	Appropriate
Shanghai	1995	2,653	9,545	1.20	Appropriate
Singapore	1987	11,827	2,800	1.37	Late
Taipei	1997	14,598	2,629	1.48	Late
Bangkok	2004	7,100	6,604	1.63	Late

* Tokyo-Ginza subway line; ** Tokyo Marunouchi subway line. Incase of Tokyo, the IPN Index for Marunouchi Line also computed since there was long break after the opening of the first line (which is not the case in other cities).

private mode. The interval estimate for average value of IPN Index is 0.73 to 1.27 (95 % confidence level). The IPN Index within the average interval value can be regarded as the appropriate time while the value below and above the interval-range may correspond early timing and late timing respectively.

Table 2 presents the IPN Index for selected cities. IPN Indices for Toronto, Tokyo (Marunouchi Line), Cairo, Seoul, and Shanghai fall within the interval values of average IPN Index indicating appropriate timings. Likewise, IPN indices Tokyo (Ginza Line), London and Paris shows early timing and those for Singapore, Taipei and Bangkok indicate late timing. The computed IPN Index yield intuitive and practically reasonable values and hence somehow validates the practical utility of the Index. However, care should be taken to interpret the index. Though it indicates the appropriate timing (within the interval), but it does not indicate the critical timing, which if surpassed, the impact of subway would be only marginal (the case of US cities as discussed above). Taipei, which takes IPN index of 1.48, was late in subway investment but it was possible to regain transit ridership as discussed above. In that sense, even a higher IPN Index of 1.48 does not indicate critical stage. On the other hand, if the Index value is higher, some other stronger complementary measures (such as parking control, good feeder service etc) may need to be implemented to ensure good ridership of subway as in the case of Taipei.

Next, the IPN Index is utilized to judge the required timing of subway investment in some East Asian megacities without subway systems. Table 3 present IPN Index for the year 2005 for Jakarta, Metro Manila and Ho Chi Minh City (HCMC). HCMC and Jakarta take value of 0.89 and 1.18 respectively suggesting that these cities are at appropriate stage to open subway system, while IPN Index value of 1.52 for Metro Manila signals that it is already late for subway investment.

Table 3 IPN Index for the year 2005 in East Asian megacities without subway

	GDP per capita (PPP 1990 $)	Population (thousands)	IPN Index
Jakarta	2,805	8,700	1.18
Metro Manila	3,750	10,900	1.52
Ho Chi Minh City	2,242	6,200	0.89

5. CONCLUSION

Even though increased motorization can be considered a natural and concomitant trend of income growth and urbanization, it is an issue of policy concern in East Asian megacities mainly because of their special characteristics. Our analysis suggests that common policy measures intended to control motorization are effective through their effects more on car use rate than on car ownership rate. This implies that as the incomes rise, increase in car ownership is simply unavoidable but car use rate can be influenced mainly by improving service level of public transport (with extensive MRT network) and/or higher user's cost for car use. The paper also puts forward an argument backed by empirical evidence that the MRT investment should be at the appropriate timing. If MRT investment is made after some critical stage, it may not bring expected impacts. Finally, a simple index for MRT timing is proposed that could help policy makers from cities without MRT system to make judgment about the appropriate timing of MRT investment.

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ANNEX

Descriptive statistics

	Mean	Std.Dev.	Minimum	Maximum	Observation
CW	301.50	208.14	7.90	746.01	54
CU	13144.40	5662.85	2647.50	27073.80	54
UD	94.52	88.18	6.36	355.65	54
INC	16599.20	12954.80	395.64	45424.90	54
PRK	265.12	346.66	2.49	1883.08	54
PT	2635.13	4541.77	129.33	27543.70	54
RLN	292.85	563.70	0.00	2850.04	54
RDS	33.33	11.55	15.00	60.60	54
BUS	696.34	493.47	81.19	3154.43	54
UCD	0.17	0.12	−0.01	0.56	54
UCC	0.24	0.13	0.04	0.65	54
SPD	9.51	10.29	−16.62	36.77	54

Correlation Matrix

	CW	CU	UD	INC	PRK	PT	RLN	RDS	BUS	UCD	UCC	SPD
CW	1.00											
CU	0.48	1.00										
UD	−0.70	−0.51	1.00									
INC	0.75	0.40	−0.49	1.00								
PRK	0.43	0.51	−0.38	0.19	1.00							
PT	0.18	−0.16	−0.16	−0.04	−0.02	1.00						
RLN	0.18	−0.07	−0.15	0.59	−0.19	−0.04	1.00					
RDS	0.73	0.66	−0.66	0.54	0.65	0.03	0.00	1.00				
BUS	−0.13	−0.21	0.03	−0.16	−0.25	0.19	−0.11	−0.22	1.00			
UCD	−0.03	−0.34	0.21	0.22	−0.21	0.18	0.09	−0.14	0.13	1.00		
UCC	0.13	−0.22	0.06	0.42	−0.15	0.13	0.26	0.01	0.10	0.95	1.00	
SPD	0.53	0.56	−0.49	0.15	0.56	0.00	−0.45	0.75	0.05	−0.19	−0.15	1.00

Definition and unit of measure	
CW	Car ownership rate (no of car per 1000 population)
CU	Annual car usage rate (Km/unit)
UD	Urban density (person per hacter of urbanized area)
INC	Metropolitan income per capita (US$/capita)
PRK	Parking space in CBD (parking units per 1000 CBD jobs)
PT	Public transport route length (meter per 1000 people)
RLN	Heavy urban rail network (Km)
RDS	Average speed of road traffic (km/hour)
BUS	No of buses in operation (units/million people)
UCD	Difference of user's cost for private and public mode (US$/pass-km)
UCC	User's cost for private mode (US$/pass-km)
SPD	Difference in average speed of private and public modes (km/hr)

List of metropolitan area included in the regression:
Abijan, Athens, Atlanta, Bangkok, Barcelona, Beijing, Berlin, Bogota, Cairo, CapeTown, Chennai, Chicago, Curitiba, Denver, Glasgow, Guangzhou, HoChiMinhCity, HongKong, Houston, Jakarta, Johannesburg, KualaLumpur, London, LosAngeles, Madrid, Manchester, Manila, Melbourne, MexicoCity, Milan, Montreal, Moscow, Mumbai, NewYork, Osaka, Paris, Phoenix, RiodeJaneiro, Riyadh, Rome, Ruhr, SanDiego, SanFrancisco, SaoPaulo, Seoul, Shanghai, Singapore, Sydney, Taipei, Tehran, TelAviv, Tokyo, Toronto, Washington