EVALUATION OF TRANSPORTATION DEMAND MANAGEMENT(TDM) MEASURES IN SEOUL: A CASE STUDY OF THE STAGGERED COMMUTING TIME SCHEME

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abstract : This paper discusses a number of transportation demand management(TDM) measures which were introduced and planned in Seoul City. The main purpose of the paper was focused on the changes of the commuter's trip patterns with staggered commuting time scheme. The analysis was based on personal interview survey which reflected travel behavior changes before and after the implementation of the scheme. One of the findings in this study was that the home-to-work trip time in the morning peak was reduced by 18 minutes and work-to-home trip time in the afternoon peak was reduced by 15 minutes as well.

1. INTRODUCTION

Since 1980 in Seoul, the continuous growth of economy brought in the rapid increase of vehicle ownership at an annual rate of over 20%. This caused various transport problems suddenly such as heavy road traffic congestion, shortage of parking spaces, high traffic accident rate, air pollution, etc.

In the last 10 years, the Seoul City had introduced a number of transportation system management(TSM) and transportation demand management(TDM) measures which help utilization of existing transport facilities more efficiently in a short term. These measures are traffic signal optimization, exclusive bus lane, strict control of illegal parking, increase of CBD parking charge and fuel tax, staggered commuting time scheme, etc. Among these, the staggered commuting time scheme was the most revolutionary measure introduced voluntarily in 1993 by several private companies including Samsung Group which is one of the three largest business groups in Korea.

The main purpose of the paper is to review the impacts of the staggered commuting time scheme. The analysis was based on the personal interview survey data which have travel behavior changes before and after the implementation of the scheme. Some advantages and disadvantages of the scheme were analyzed in terms of spread of traffic demand and traffic congestion during the morning and afternoon peak periods.

2. CURRENT TRAFFIC CONDITIONS IN SEOUL

2.1 Increase of Traffic Demand

Korea's rapid economic growth has spurred an unprecedented nationwide increase in demand for transportation of passenger and freight. Specially, the traffic demand in Seoul City had increased dramatically since 1970 with the urbanization and personal income growth. Table-1 shows the change of traffic demand in Seoul. During the year of 1970 and 1992, population of Seoul City increased only by 2.0 times but daily person trip increased by 4.2 times. Moreover, the number of vehicles increased by 32.0 times and passenger car by 40.2 times as well. This cause a number of transportation problems such as road traffic congestion, traffic accident, air pollution, and so on.

Table-1. Trend of Traffic Demand in Seoul

Items	Unit	1960	1970	1980	1990	1992	1994
City Area	km^2	268	613	627	627	627	627
Population	1,000 persons	2,450	5,536	8,366	10,726	10,976	10,799
Daily Person Trip	1,000 persons	NA	6,170	12,670	24,638	25,715	26,440
Total Vehicle	1,000 vehicles	7.8	60.4	206.8	1,193.6	1,563.0	1,932.2
Passenger Car	1,000 vehicles	4.2	36.9	130.5	883.4	1,194.0	1,498.9
Share of Passenger Car	%	53.8	61.1	63.1	74.0	77.6	77.6
GNP per Capita	US$ / person	NA	234	1,592	5,569	6,749	

2.2 Road Traffic Condition

Road traffic condition is decided by the supply of road and the demand of traffic. According to Table-2, road length during the year of 1970 and 1990 increased by 1.4 times which could not follow the increase of traffic demand. As a result, peak hour travel speed of vehicles in the CBD of Seoul City became 19.3 km/hr in the year of 1992 from 30.8 km/hr in the year of 1980 as shown in Figure-3. The traffic congestion cost of Seoul City was expected to be about 1,368 billion Won(1.7 billion US$) which was consisted of vehicle operation cost and travel time loss for the year of 1991.

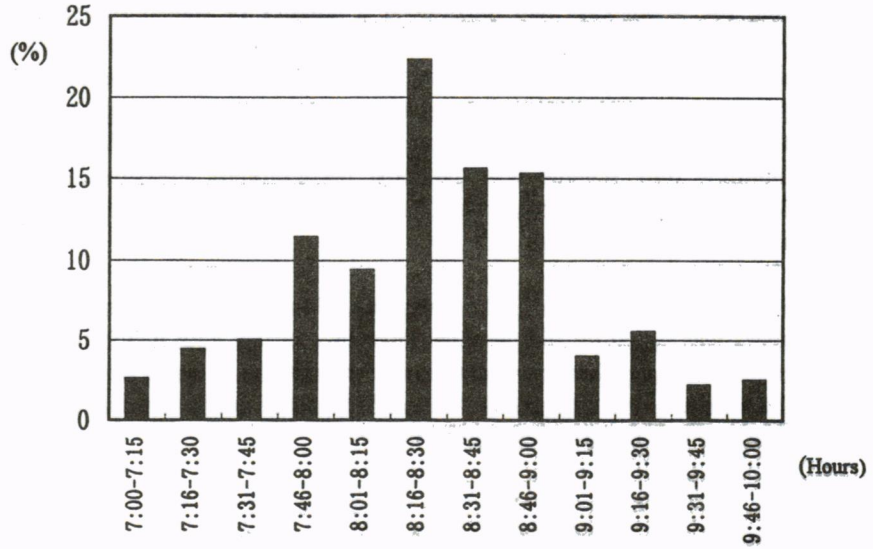

Figure-1. Distribution of Arrival Time in the Morning for the Work and School Trip

Table-2. Trend of Road Supply in Seoul City

Items	Unit	1970	1980	1990	1994
Road Length	km	5,286	6,610	7,375	7,621
Road Area	km^2	35.0	56.2	68.6	73.4
Road Ratio	%	9.6	15.0	18.3	19.6

Table-3. Peak Hour Travel Speed in the CBD of Seoul City

Item	Unit	1980	1984	1988	1992
Travel Speed	km/hr	30.8	25.2	20.5	19.3

2.3 Construction of Subway and Urban Highway Network

Seoul City opened Subway Line 1 from Seoul Station to Chungryangri in 1974 and opened Line 2, Line 3, and Line 4 in the middle of 1980's as shown in Table-4. But, there was no additional subway construction until the end of 1980's, so it accelerated to increase the number of passenger car and use of it. Seoul City started to construct another 4 lines of subway in the early of 1990's and it is still under construction. Current subway network in Seoul is 123 km, but it will be 268 km in 1997 with the construction of Line 5, Line 6, Line 7, and Line 8.

With the completion of these subway network, mode share of the subway will be enhanced up to 50% , but it is still lower than that of other big cities such as Tokyo, London, Paris, and New York in developed countries. Seoul City is planning to construct another four lines of subway network which is about 120 Km in its length and on the process of basic design now.

Also, Seoul City planned to expand its urban highways network more than 4 times comparing in the year of 1993 before the year of 2000 for the increase of rapid road traffic demand as shown in Table-5. Urban highway expected to accommodate bypass traffic which will mitigate downtown traffic congestion.

Table-4. Subway Line of Seoul City in Operation and Under Construction

Line No.	Sections	Open Year	Length	Stations
Line 1	Seoul Station-Chongnayangri	1974	9.5 km	9
Line 2*	City Hall-Kangnam-City Hall	1985	57.3 km	48
Line 3	Chichuk-Yangjae-Suso	1986	36.9 km	30
Line 4	Namtaeryong-Tangkogae	1987	34.3 km	26
Line 5*	Kimpo Airport-Kodok	1995	52.0 km	52
Line 6	Yokchon-Shinnae	1997	31.0 km	38
Line 7	Onsu-Tobongsan	1997	42.0 km	41
Line 8	Amsa-Bokchong	1997	20.0 km	17
Total			268.0 km	261

* Remarks : Line 2 and Line 5 include its Branch Line.

Table-5. Current and Planned Urban Highway and Major Arterial Road of Seoul City

Type of Road	Unit	1993	1997	2001	Long Term
Urban Highway	km	130	331	543	613
Major Arterial Road	km	603	620	696	865

2.4 Introduction of Transportation System Management

With the rapid increase of road traffic demand and lacks of transportation infrastructure, Seoul City introduced several Transportation System Management(TSM) measures to maximize the efficiency of its existing transportation facilities in 1980's. These measures include signal optimization, intersection design improvement, one way road, variable road lane, and adjustment of bus stops.

Implemented TSM measures are evaluated to be effective for the relief of traffic congestion, enhancement of downtown vehicle travel speed, and mitigate travel accident as Table-6. But these TSM measures are restricted for a local transportation improvement only for a short term and need to be continued with the long term transportation improvement.

Table-6. Effects of TSM Measures in Seoul City during 1985-1991

Implemented Area	Intersection Improvement	Traffic Accident Change	Peak Travel Time Change	Congestion Rate Change
17 Arterials* of 5 Area	502 Intersections	- 27.0 %	+ 6.8 %	- 10.0

* Remarks : 17 Arterials are about 283.1 km in total length.

3. MAJOR TDM MEASURES CONDUCTED AND PLANNED IN SEOUL

Even with the continuous construction of transportation facilities, Seoul City's transportation problems was getting worse in 1980's. Also revenue for the transportation facilities was limited comparing the need for demand. Therefore, Seoul City tried to introduce many transportation demand management at the middle of 1980's. These measures are exclusive bus lanes, vehicle number plate restriction, mandatory garage requirement, traffic impact assessment, traffic generation tax, and staggered commuting time scheme, which will be explained as follows more in detail.

3.1 Exclusive Bus Lanes

Comparing with the Capitals of developed country such as London, New York, Paris, and Tokyo, Seoul City does not have enough subway and urban railway network. Mode share of bus was decreasing successively from 67.0% in 1978 to 38.8% in 1992 but still biggest mode share in Seoul. Also, bus transportation in Seoul City have very good network with 422 routes and operated by private companies at low fare level without government subsidy at all for its operation cost.

Table-7. Change of Mode Share of Transportation

Type of Mode	1978	1983	1988	1992	1994
Bus	67.0%	64.3%	50.6%	38.8%	38.0%
Subway	7.0%	10.0%	16.8%	24.6%	28.5%
Taxi	19.5%	17.0%	16.0%	12.0%	9.7%
Passenger Cars, etc.	6.5%	8.7%	16.6%	24.6%	24.0%

First exclusive bus lane was installed in 1984 for the first time in Seoul but was not operated effectively. In the beginning of 1990's, Seoul City started to control violation of bus lanes strictly by the police and city officials to recover the role of bus and expanded its route up to 123 km of exclusive bus lane at 25 sections. Moreover, Seoul City is planning to install another 146 km of exclusive bus lanes at 41 sections in the future as shown in Table-8.

Seoul City evaluated the effect of 15.1 km of 3 exclusive bus lanes which installed at the end of 1994. City surveyed the change of traffic volume and travel speed before and after the lane installation so as to estimate benefit by exclusive bus lane installation. According to the results of the estimation, the benefit calculated as 15.1 million US$ per year for 15.1 km of 3 exclusive bus lane as shown Table-9.

Table-8. Exclusive Bus Lane of Seoul

Items	No. of Section	Route Length	Remarks
In Operation	25 Section	123 km	Before 1994
Under Planning	41 Section	146 km	After 1995

Table-9. Benefit Estimation by Exclusive Bus Lane Installation in Seoul

Items	No. of Section	Route Length	Benefit in Korean Won	Benefit in US $
Surveyed Lane	3 Sections	15.1 km	12.08 billion Won/Year	15.1 million US $/Year
Total Lane	25 Sections	123.0 km	2,393 billion Won/Year	2.9 billion US $/Year

3.2 Vehicle Number Plate Restriction

Vehicle number plate restriction was introduced in Seoul City during 1988 Seoul Olympic Game for the first time to enhance traffic flows speed and enforced again Gulf War to save gasoline. At the beginning of 1995, it was enforced again to reduce traffic flows for the overall repair of Bridges on Han River after the collapse of Sung-su Bridge during its repair. Seoul City restricted vehicle operation of private vehicles which have same final vehicle plate number with the final number of the date. In case of violation, City Police fines to the driver.

Seoul City surveyed changes of traffic volume and vehicle travel speed just before and after the vehicle number plate restriction. City surveyed 2 places for traffic volume changes and 10 places for vehicle travel speed changes. According to the survey results, the benefit

were estimated to be 80.9 million US$ per day for Seoul City which is consisted of 52.3 million US$ of time value saving and 28.6 million US$ of vehicle operation cost saving.

Table-10. Traffic Volume and Travel Speed Change with Vehicle Number Plate Restriction

Item	Before	After
Traffic Volume	87,187 Vehicles/Day	80,779 Vehicles/Day
Passenger Car Travel Speed	27.8 km/hr	31.58 km/hr

3.3 Mandatory Garage Requirement

Mandatory Garage Requirement is a garage registration system to enroll a garage for every passenger car. One of the serious transportation problem in Seoul is illegal parking of passenger car and this requirement is mainly to prevent illegal parking at residential area. Seoul City had 130.5 thousands of passenger car in 1980 but increased to 883.4 thousands in 1990 which is almost 7 times in the period of 10 years with the annual increase rate of 21.1%. This resulted in the lack of garage and Seoul City experience serious illegal parking problems at residential area as well as downtown. The ownership of passenger car will be continued to increase rapidly for the next 10 years as well.

Mandatory Garage Requirement introduced only by Japan in 1960's and Seoul City was considering to introduce it since 1989. An advance notice for the enactment of this law was publicized in 1993 and was planned to be introduced in Seoul City in the year of 1996.

3.4 Traffic Impact Assessment

Traffic Impact Assessment is prior evaluation of traffic impact by new building construction or area development which may have serious traffic impact on the existing road. This is introduced to prevent worsening of existing traffic conditions with new building or development. This assessment was firstly introduced in 1985 and continued by Seoul City without legal obligation until Urban Transport Act was publicized in 1987.

The number of traffic assessment in Seoul is almost 500 by the end of 1992 as shown in Table-11. Sponsor of the new building or development should follow the decision of the committee board for the traffic impact assessment. The decision includes construction of new road, improvement of existing road(expansion, geometric design, signal optimization, etc.), improvement of access road, enlargement of parking facility, public transportation access facilities.

Table-11. The Number of Traffic Impact Assessment in Seoul

Year	1987-1988	1989	1990	1991	1992	Total
Number	55	71	107	132	124	489

3.5 Staggered Commuting Time Scheme

Staggered commuting time scheme is a form of alternative work schedules which is one of TDM measures to disperse peak hour traffic demand by adjusting working hours. Alternative work schedule is an obvious means of reducing peak hour congestion to spread the peak. This can be done if employers are more flexible with their employee's working hours.

Staggered commuting time scheme is to change the work schedule for whole company for all of the employee. This scheme was attempted to be introduced by Seoul City to mitigate peak hour congestion but it could not be realized with concerns of side effects. On the other hand, several private companies introduced staggered commuting time scheme voluntarily in 1993 to relief their employee from traffic congestion and enhance work efficiency. The result was very successful in the view point of company's goal. They could lessen commuting time of their employee and could achieve improvement of working conditions in several aspect.

4. EVALUATION OF STAGGERED COMMUTING TIME SCHEME

4.1 Implementation by Private Company

Staggered commuting time scheme was initiated by small sized company named Tae-heung Leather Company in the January of 1993. Before the implementation of staggered commuting, this company started work at 8:30 a.m. everyday and finished around 7:00 p.m. President of this company wanted to reform management so as to lessen commuting time in the morning and in the afternoon. Some of the employee were reluctant to start work early because it may simply extended the working hours and change life cycle. After the introduction of the scheme, company controlled strictly to finish their work at 4:30 p.m. so that they can have more free time in the afternoon. Of course, they could save their commuting time in the morning and afternoon as well.

Other companies including Samsung Business Group which is one of the three largest business groups in Korea introduced staggered commuting time scheme as Table-12.

Table-12. Companies Introduced Staggered Commuting Time Scheme

Name of Companies	Change of Working Hours	Number of Employee	Date Started
Taehung Leather Co.	08:30-19:00→06:30-16:30	150	Jan 21, 1993
Samsung Business Group	08:30-19:00→07:00-16:00	120,000	Jul 7, 1993
Samheung Mechanical Co.	09:00-19:00→07:00-16:30*	250	
Cricket Boiler Co.	08:30-18:30→07:30-17:00	180	
Nara Planning Co.	08:30-18:00→08:00-17:30	63	Jul 1, 1993
Bukuk Securities Co.	09:00-18:00→08:00-17:00	396	Sep 1, 1993

* Remark : In case of Samheung Mecanical Company, working hours are a little different by positions of employee.

4.2 Personal Interview Survey

To evaluate the effect of staggered commuting time scheme, personal interview survey was conducted in the September of 1993. Questionnaires were distributed for about 300 personnel of the companies in Table-13 which introduced the scheme in 1993, and 198 questionnaires were returned which were eventually usable. Table-14 is showing the outline of the survey respondents. Five questions were asked to the respondents which include commuting time, mode of commuting, preference of the scheme, comfort, and change of sleeping hours as shown in Table-15.

Table-13. The Number of Questionnaires Distributed and Returned

Items	Taehung Leather Co.	Samsung Group	Nara Planning Co.	Bukuk Securities Co.
Distributed	40	180	30	50
Returned	28	136	12	23

Table-14. Outline of the Respondents of Personal Interview Survey

Sex		Age					Car Ownership	
Male	Female	Below 25	26-30	31-35	36-40	Above 41	Yes	No
151	47	31	65	68	28	6	87	111

Table-15. Contents of the Questionnaires

Question Items	Contents of the Question
1. Commuting Time	- When did you depart home and arrive office before and after the scheme ? - When did you depart office and arrive home before and after the scheme ?
2. Mode of Commuting	- What mode of transport did you used for work and home trip before and after the scheme ?
3. Preference of Scheme	- Do you like the scheme or not, and why ?
4. Comport	- How was the comfortable for work and home trip after the implementation of the scheme ?
5. Change of Sleeping Hours	- How long did you sleep before and after the scheme ?

4.3 Summary of the Survey Result

4.3.1 Commuting Time

One of most remarkable aspects of the staggered commuting time scheme is the change of commuting time. Figure-2 is showing changes of depart and arrive time before and after the scheme. Table-16 is the summary of survey results on the average depart time and arrive time for home to work and work to home trip.

According to the survey result, the average time to leave home in the morning was 7:01 a.m. and took it about 56 minutes before the implementation of the scheme, but it was 5:59 a.m.

and took it about 38 minutes after the scheme to arrive the office. Also they left office 7:18 p.m. and took it about 69 minutes before the scheme but they left 4:30 p.m. and took it about 54 minutes after the scheme to arrive home. Therefore, employee could save 18 minutes for home-to-work trip time in the morning peak period and could save 15 minutes for work-to-home trip in the afternoon peak.

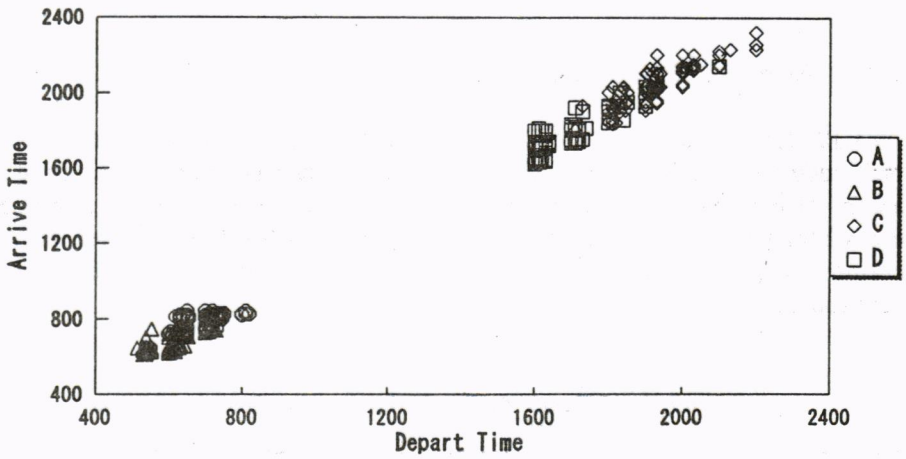

Figure-2. Change of Depart and Arrive Time

※ Remarks : A and B are depart and arrive time in the morning before and after the scheme. C and D are depart and arrival time in the afternoon before and after the scheme.

Table-16. Change of Commuting Time

Item	Home-to-Work Trip (Average)			Work-to-Home Trip (Average)		
	Depart (A)	Arrive (B)	B-A	Depart (A)	Arrive (B)	B-A
Before Scheme	07:01	07:57	56	19:18	20:27	69
After Scheme	05:59	06:37	38	16:30	17:24	54

4.3.2 Mode of Commuting

Change of commuting transport mode is remarkable in the morning for the home-to-work trip. Before the scheme, 45.5% of the respondents used subway in the morning, but it become 17.7% after the scheme as shown in Table-17. Instead of that, share of the bus increased by 11.1%, passenger car by 5.0%, commuting bus by 12.7% and this was due to the vehicle travel speed variation in the morning peak hours.

In the afternoon mode of transport, there were remarkable changes as morning trip as well. Mode share of subway for work-to-home trip decreased by 20.9% and mode share of bus increased by 17.3% on the other hand. This was due to the bus travel speed enhancement in the afternoon peak as well.

Table-17. Change of Commuting Transport Mode Share

Type of Trip		Subway	Bus	Passenger Car	Commuting Bus	Taxi, etc.
Home-to-Work	Before	45.5%	20.7%	15.7%	15.1%	3.0%
Trip	After	17.7%	31.8%	20.7%	27.8%	2.0%
Work-to-Home	Before	51.0%	30.3%	15.2%	1.5%	2.0%
Trip	After	30.1%	47.6%	19.3%	1.0%	2.0%

4.3.3 Preference of the Scheme

Table-18 shows that 97.5 % of the respondents was preferable to have the staggered commuting time scheme. Most of them liked the scheme because they can have more free time in the evening and can avoid traffic jam. This means that the staggered commuting time scheme is secondary benefit for the employee. Also, the employer introduced the scheme to enhance the efficiency of the work of the employee for the reformation of the management.

Table-18. Survey Result on the Preference of the Scheme

Preference	Reasons	Percentage
Agree	- Can be possible to have more free time in the evening.	77.9 %
	- Can avoid to have traffic jam.	14.6 %
	- Can enhance the efficiency of work in the morning.	3.5 %
	- Others	1.5 %
Disagree	- Because of change of life rhythm.	1.0 %
	- Because of extension of working hours.	0.5 %
	- Others	1.0 %

4.3.4 Comfort of Transport Mode

The congestion rate inside of a subway and bus is much different by time in the morning and in the afternoon in Seoul. During 8:00-9:00 a.m. in the morning, most of subway have congestion rate more than 250% in which it is impossible to read even a small book. But, congestion rate will be around 100-150% during 6:00-7:30 a.m. In the afternoon, it will be less congested before 6:00 p.m. when most of companies finish their work.

Survey results in Table-19 shows that about 70-80% of the respondents feel comfortable by the implementation of the scheme. This is mainly for the avoiding most congested period of transport mode and use of commuting car.

Table-19. Changes on Comfort of Transport after the Scheme

Items	Very Comfortable	Comfortable	Same as Before	Uncomfortable	Very Uncomfortable
Home to Work Journey	44.5 %	34.8 %	18.7 %	1.5 %	0.5 %
Work to Home Journey	20.7 %	50.0 %	26.8 %	2.5 %	0.0 %

4.3.5 Change of Sleeping Hours

Staggered commuting time scheme is to start work early in the morning and finish early in the afternoon as well. But living environments are not so different as before, for example TV broadcasting hours, meeting time with friend, and telephone call from the other person. Therefore the member of the company which introduced the scheme tend to sleep late in the evening in spite of their early wake up in the morning.

According to the survey result, the respondent slept about 6 hours and 26 minutes before the scheme but they slept about 5 hours and 50 minutes so they sleep 36 minutes less than before.

5. CONCLUSION

Seoul City experiencing a number of transportation problems since 1980's by the rapid increase rate of vehicle ownership with about 10-20% of annual increase rate and started to introduce several Transportation Demand Management(TDM) measures as reviewed briefly in this paper. These TDM measures include exclusive bus lanes, vehicle number plate restriction, traffic impact assessment, etc., which was introduced by Seoul City Authority. Beside these, there had been many other means of TDM measures such as parking price increase, carpooling, gasoline tax increase, park-and-ride, and so on which implemented in Seoul. Congestion road toll and employer-based TDM measures are planned to be implemented in the near future.

These TDM measures, of course, cannot solve transportation problems completely by themselves. Successful TDM measures should be integrated with other transport policies and should have good cooperation with private sectors as well. Staggered commuting time scheme is good example in that sense because it tried to be introduced by City Authority and failed. Private companies could make it successful by fulfilling the need of their employee. They started and finished their work much earlier than other companies and reduced the working hours by enhancing the efficiency of works. The company strictly controlled to finish their work early in the afternoon so their employee can have more free time after the work.

Of course there might be inconvenience by introducing staggered commuting time scheme but it was going well up to now with good reputations. For the introduction of new polices, as like staggered commuting time scheme, most important thing is to maximize the utilities of each individuals and it will result in successful polices.

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