ANALYSIS OF TRAM RAILWAY EXTENSION POLICY USING MULTI-AGENT BASED TRAFFIC SIMULATOR

Takafumi Sakurai, School of Engineering, University of Tokyo

sakurai@save.sys.t.u-tokyo.ac.jp

Shinobu Yoshimura, School of Engineering, University of Tokyo

yoshi@sys.t.u-tokyo.ac.jp

Hideki Fujii, School of Engineering, University of Tokyo

fujii@sys.t.u-tokyo.ac.jp

ABSTRACT

The Kyoto Protocol has been valid for four years and now the world is arguing about after the Kyoto Protocol. The figures of arguments result are still obscure but new protocol will be required higher emission rates for industrial countries than the Kyoto Protocol. Transportation has a big impact on the influence of natural environment and has been required outstanding development especially on energetic efficiency and reducing the emission gas. These requirements bring the public transportation to in the spotlight again at all over the world. Furthermore, developing countries also pay attention for the public transportation as one of the valuable ways for decreasing the traffic congestion not only the reasons come from the global warming issues. Urban traffic policy makers, therefore, need to consider how to combine the existence traffic systems and new traffic systems. The lack of this consideration has huge potential to end with the undesirable results. In our study, we raise the tram railway extension plan in Okayama Prefecture, Japan as an example and discuss its impact for current traffic flows using a Multi-Agent based Traffic and Environment Simulator (MATES). MATES has been developing at our laboratory since 1999 to analyze complex traffic systems and effect of various traffic policies. We have analyzed real traffic phenomena using MATES but we expand and utilize its abilities to measure the economic impacts as a new attempt in this time. In the past, traffic simulators used only for analyzing the traffic flow and recreating the driver's behaviours. Then investment values from new traffic policies were measured another specific calculations or methods. Both topics are strongly tied and have a relationship but often considered separately. Thus, we suggest one proposal how to combine the traffic simulator and its result with economic analysis. In the economic analysis field, we introduced a real option analysis to evaluate the aspects of traffic investment's uncertainty in precise as much as possible. The study results come from a multilateral perspective and indicate new figure of transport investments via financial options.

Keywords: Traffic simulator, Multi-Agent, Real option, Traffic flow analysis

INTRODUCTION

A figure of traffic flow represents one of main complex phenomena and it is not easy to clarify that what sorts of traffic situations should be defined as traffic problems. It depends on the point of observer's views. We can say, although, one of the major traffic problems around our social daily life is a traffic congestion problem in cities. In Japan, the Japanese government estimates an annual economic loss which suffers from traffic congestion is about $120 billion, this number indicates each Japanese citizens loses about $1,000 per year. A view from lost time, 3.8 billion hours in all parts of Japan and this number means every Japanese people loses about 30 hours every year due to traffic congestion. As you already know, traffic congestion isn't a new problem and has been considered as one of a typical traffic problems for a long time. But this problem is still standing in front of us around the world and a lot of policy makers are struggling to solve it.

In 1997, the United Nations Framework Convention on Climate Change (UNFCC) took place in Kyoto, Japan and the Kyoto Protocol was agreed. The Kyoto Protocol has validated from January 2008 and it requires the ratifying countries to take actions for emission gas cut. For Japan, the Kyoto Protocol requires to reduce six percent of total amount of emission gas compare with 1990. At present, but, total amount of emission gas increased 8 percent in Japan. The government declares ambitious plans to deal with this problem but current economic situations and social background make it more difficult and complex. In Japan, industrial activities discharge 40 % of total amount of emission, 25 % by people's livelihood, following traffic sector is occupying 22 %. The total volume of traffic activities, a division of private automobiles makes up 56 %, commercial cargo holds 17 %, private cargo holds 12 %, buses and taxies hold 4 %.

It is an obvious that traffic is core part of our social lives and necessary for world economic activities. Our lives cannot maintain without a benefit from traffic but we also cannot draw a bright future under the unstoppable global warming world. Traffic engineering can give useful and beneficial suggestions on this matter and the world is waiting for it. Past century, traffic engineering was mainly expected to give insights on only traffic problem fields. Nowadays, its roles have drastically increased and its influence in the international society has widely spread.

OBJECTIVES

Traffic simulators have various positive points to analyze traffic phenomena and traffic problems. Generally, it is not easy and realistic to experiment traffic phenomena on the local roads especially large scale of traffic experiments because of costs, a lot of restrictions, time and so on. In regard to this point, traffic simulators are able to exercise its ability, expandability, flexibility and precise measurement. A massive progress of calculation speeds, furthermore, gives developers and users to increase a merit of traffic simulations. The drastic development of the CPU for the past a few decades was enough to motivate us to use its power and ability. And, parallel processing computers has become moderate prices and its usage information is found very easily via internet now. These computational environmental shifts give opportunities for a lot of people to use cutting-edge computational technologies. In the traffic engineering fields, this trend is observed too and it can be said that traffic engineering is one of the biggest areas which are receiving a benefit from the development computational technologies.

In this paper, firstly, we discuss a multi-agent based traffic simulator which is developing at our laboratory. Its characteristics, structural design, agent behaviour definitions and advantages are explained as we see later in this paper.

Secondary, we introduce a background and aim of a tram railway extension plan in Okayama City, Japan. And we also refer here to recent movement of tram railway constructions in Japan. The role of trams and its social values have slightly improved especially local cities and the government offer some financial aids for constructing new tram railways.

Thirdly, we analyze an impact on tram railways extension plan in Okayama by our traffic simulator, then, show some meaningful results and sights.

Finally, the biggest purpose of this paper comes. We propose a way of combination of the traffic simulator and economic analysis. We expand results of traffic simulator analyses to use it for economical analysis. We introduce real options approach to measure uncertainty in as precise as possible.

Throughout this study, we place an emphasis on multilateral analyses and quantitative analyses to evaluate a real value of tram railway extension plan from both traffic engineering views and economic aspects.

MULTI-AGENT BASED TRAFFIC SIMULATOR *MATES*

Brief overview of *MATES*

A traffic simulator *MATES (Multi-Agent base Traffic and Environment Simulator)* has been developing since 1999 at Yoshimura Laboratory, University of Tokyo. The main purposes of developing this simulator are described below.

1. Recreation of complex traffic phenomena
2. Refinement of traffic players behaviours
3. Predictions for traffic flows transitions
4. Ability for measurement of ITS (Intelligent Transportation Systems) effect

One of the main characteristics of MATES is a concept of multi-agent structure. We believe that real traffic world is consisted by tremendous number of traffic player's interactions. This recognition motivated us to introduce the multi-agent structure instead of fluid dynamics models. In multi-agent systems, it is necessary to prepare an environment which agents will play on it and play under the given rules. In MATES, we define traffic entities like automobiles, pedestrians as agents and also defined player's playing fields (mainly roads) as the environment. A term of the environment includes not only roads but also traffic lights, traffic signs, buildings and obstructions on the roads. In the broad sense, traffic regulations are considered as one of traffic environment, too. Furthermore, a view from a *vehicle agent A*, other vehicle agents is also regarded as the environment. It means all agents around him except himself are considered as the environment from the *vehicle agent A*.

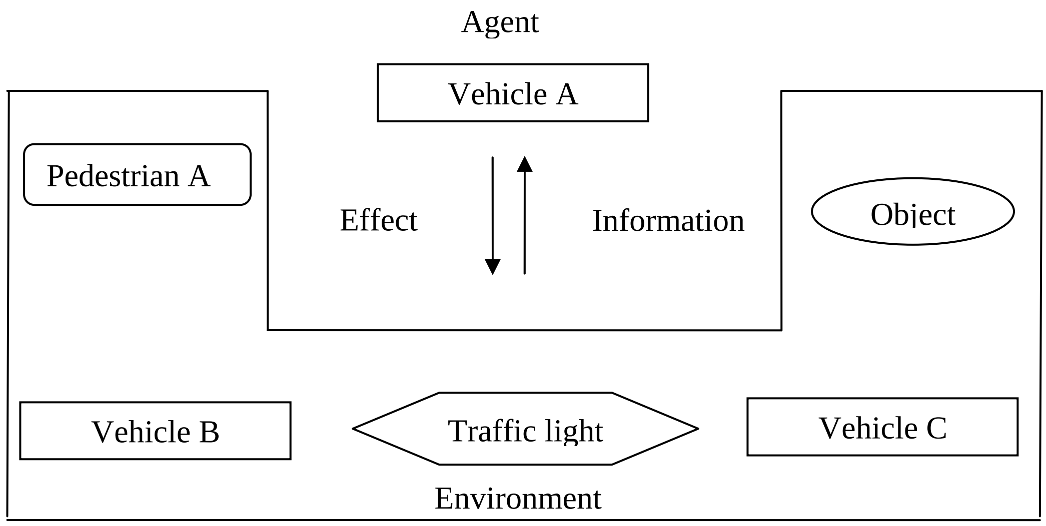

Figure 1 Relationship between agent and environment

Every time steps, each agent accesses to the environment to obtain information around him. Then agents decide their decisions under the given decision making process flows. Their autonomous decisions affect on the environment via their actions. Thus actions by the *vehicle agent A* will change the environment of a *vehicle agent B* and vice versa. Large number of these iterations will let recreate interactions among all agents and the environments. The results of these interactions have possibilities for emergent properties and can emerge complex phenomena.

Definition of agent

As mentioned above, in MATES, we deal with vehicles, trams and pedestrians as agents. Generally, agents are regarded as "self-driven entities". To be precise, therefore, drivers of vehicles or trams are considered as agents but there is no need to distinguish drivers and vehicle's behaviours. Thereby, driver's behaviours are represented by vehicle's behaviours and their behaviours can see almost a same. Consequently, designing vehicles behaviours means designing driver's behaviours.
Traditional traffic simulators had to simplify driver's behaviours because of its calculation costs. We implemented relatively a large number of functions to recreate driver's behaviours as much as possible. But unfortunately we have to admit that there is a limit. It is obvious that drivers always pay much attention for their sight information and always try to find the best decision each time. MATES have a function to make a decision for visible objects or invisible objects and result of this function affects on vehicle's decision makings. But information from

sight is not enough to make decisions. For instance, drivers try to collect current their situations from their ears (e.g. sound of other vehicles), from vibrations (e.g. vibration from tyres) and also from their experiences. These senses may be insensibility behaviours but very important for safe driving. Although to implement these senses to simulators is still not easy and usually avoided.

Some traditional traffic simulators didn't consider route choice problems totally or not considered to be important. Even some traffic simulators had route choice functions, most of them were only implemented very simple Origin-Destination models. But in the real world, drivers have or receive various information and after due consideration those information then they select their route. Sometimes, two drivers have same information and same origin-destination but their route choices will be different because of driving skill (learner's license driver or skilled driver), the number of traffic lanes and so on. How to treat individual tastes are very complicated and controversial issues. In MATES, we introduced some driver's models and when vehicles generate, characteristics are assigned stochastically. This is a temporary solution but useful for increasing reality.

The important rule of multi-agent simulator is agents can decide their decisions by themselves without external interference or user's prejudices. Their decision always should be done independently by themselves. If users intend to modify agent's behaviours definitions to lead to obtain desirable results, interactions among intended agents create non-valuable data.

Below sections are describing some important agents autonomous and its characters.

Vehicle agents

Already described above, MATES has some utility functions for route choice procedures to represent various types of drivers.

<Autonomous on the road>

- Planning (origin and destination)
- Route search
- Route choice

<Driving abilities>

- Knowledge of traffic rules
- Velocity management
- Lane change, merging and fork
- Right turn and left turn in the intersections with other agent-conscious
- Route selection on the road

Vehicle agents drive on so-called *virtual driving lanes.* This concept is almost same with trains drive on the rails. In MATES, there are invisible driving lanes on the streets and vehicle agents drive on it. This concept also fit for tram agents.

Tram agents

It is very important for trams to maintain on time schedule running. Passengers are usually expected this point and not small number of passengers use trams because of its on time running. If tram had own lanes like trains, things are not so complicated to keep on time schedule. But they often share the lanes with vehicles, buses and other vehicles. And when they cross the intersections, they will suffer from traffic flow conditions and not easy to keep driving at a constant speed. Therefore, tram agents must have ability for the velocity adjustment function to keep on time schedule.
In addition, interactions between vehicle agents and tram agents inside intersections are differ from interactions among vehicle agents since most of Japanese tram railways are constructed the middle of streets. When tram agents turn left at an intersection, they have to cross vehicle lanes for through traffics. In this situation, which agent should have a priority? To deliberate about this problem appropriate way will help the on time schedule.

<Driving ability on the tram railways>

- Let passengers to board and exit at tram stations
- Time schedule-conscious velocity control management
- Flexible behaviours management due to priority problems at intersections

Pedestrian agents

Characters of pedestrian agents are essentially differed from vehicle agents and tram agents. At this stage, pedestrians are only allowed to walk on zebra crossings and zebra crossings are only installed at intersections (A new version of MATES, pedestrians can walk on the sidewalk). At first, we assume that interactions between pedestrians and vehicles only happen at the intersections. This idea also aimed to avoid the cost of unnecessary calculations. Purposes of pedestrians are to cross the zebra crossings or to reach tram stations on the middle of streets, thus pedestrians don't need to have a function of large scale route choices. Furthermore, behaviours also quite differ from vehicle agents and tram agents. This reason comes from a lane dimension difference between them. Lanes (*virtual driving lanes*) for vehicle agents and tram agents are designed one dimensional coordinate to avoid unnecessary calculations. In other words, direction of movement for vehicle agents and tram agents are limited only go forward and go backward. On the other hands, dimensions for pedestrian agents have two dimensional coordinate. Since pedestrian agents need a two dimensional information when they move out of the way of other pedestrians.

TRAM RAILWAY EXTENSION PLAN IN CITY OF OKAYAMA

Summary of city of Okayama

At the point of 2007, the population in city of Okayama is about 0.7 million and the second largest city after city of Hiroshima in the Chugoku region. Since 1996, Okayama City has been assigned one of core city in Japan by the government and the city of Okayama

government asks for a permission to become an ordinance-designated city. In the 21st century, a lot of Japanese local cities are facing a declining population. Under such circumstance, population in Okayama City is slightly increasing and seemingly it is relatively enjoying solid growth from the impression of statistical figures. But these positive numbers came from consolidation of two towns in 2005 and also merged with two towns in 2007 again. These absorptions gave an impact on increase of population in suburban areas but on the other hands population in the centre of Okayama are deeply decreasing as in other many local cities.
Citizens in Okayama normally choose vehicles as their main mobility method and result of this makes various number of traffic problems. Under the severe conditions, at present, there are two tram lines (Higashiyama Line and Seikibashi Line) operating.

Tram railway extension to in front of Okayama station

Revitalizing the center of Okayama is necessary for drawing a bright future of Okayama City. A lot of ideas have proposed by citizens, universities, economic organizations and NPOs. RACDA, one of the NPOs in Okayama, is proposing a tram railway extension to in front of Okayama station. Okayama station is the biggest station in Okayama Prefecture and owned by West Japan Railway Company. There is around 220 meters distance between Okayama station and the nearest tram station (*Okayama Ekimae Station*). RACDA has proposed to extend tram railway to in front of Okayama station's open space. The number of 220 meters extension is very short but from *Okayama Ekimae Station* to Okayama station takes about 5 – 6 minutes for average pedestrians. Pedestrians have to cross the intersection which is one of the busiest intersections in Okayama in front of Okayama station. And waiting for the traffic light to change occupies the biggest part of travelling time.
Okayama station is one of the largest stations in the Chugoku area and all *Sanyo Shinkansen* known as the bullet train stop at this station. This major station is used by a lot of business people, students, elderly people and tourists everyday. Therefore increase of mobility between two stations will improve benefit for users. And tram operator expects the growing of the number of passengers. A redevelopment of in front of Okayama station has been discussed for a long time and some people anticipate that tram railway extension will trigger a movement of redevelopment around Okayama station among citizens. Reallocations of bus stops at Okayama station have already done and RACDA plan advocates harmonizing trains, buses and trams.

Concerns on tram railway extension

Citizens of Okayama have some sense of impatience for future of their city. They feel that the city of Okayama government needs to draw a new city design. Those movements accelerate the redevelopment of Okayama station district, too. There, although, are some concerns reported for tram railway extension. The biggest and is widely spoken concern is a serious negative effect on traffic flows around Okayama station. This concern is an expected since the intersection which is in front of Okayama station is one of the busiest intersections. Especially during morning and evening commuting, there are already heavy traffic

congestions observed. If tram railway extended to in front of Okayama station, the number of lanes for the vehicles will be decreased in spite of invariable traffic volumes. Therefore a lot of people have a concern on tram railway extension plan even the convenience and value of social transportation will be increased. Actually, this concern comes from the stereotype or fixed concept of “tram railway extension always leads to negative impact on traffic flows” but need deeply considerations to ease people’s anxieties.
Moreover, there is a very important problem is lying. It is a financial problem. Who will cover the investment for tram railway extension? Both Okayama City and Okayama Prefecture don’t afford an unsound project. Okayama Electric Tramway Co Ltd. who is operating trams also facing a very severe financial condition and managers cannot make a decision for investment without the possibility for reward from investment.

TRAFFIC ANALYSIS AFTER TRAM RAILWAY EXTENTIONS

Figure of after tram railway extension

A network structure before tram railway extension, in other words, the intersection in front of Okayama station at present is shown Figure 2 and Figure 3 represents after tram railway extensions. As you can see two figures, trams will run straight through the intersection after extensions.
Actually, there are some other extension plans proposed but Figure 3 seems the highest operability plan. We also considered other extensions plan and did the simulations. The result showed that Figure 3 is the most appropriate plan. Hence we only discuss Figure 3 extension plan in this paper.

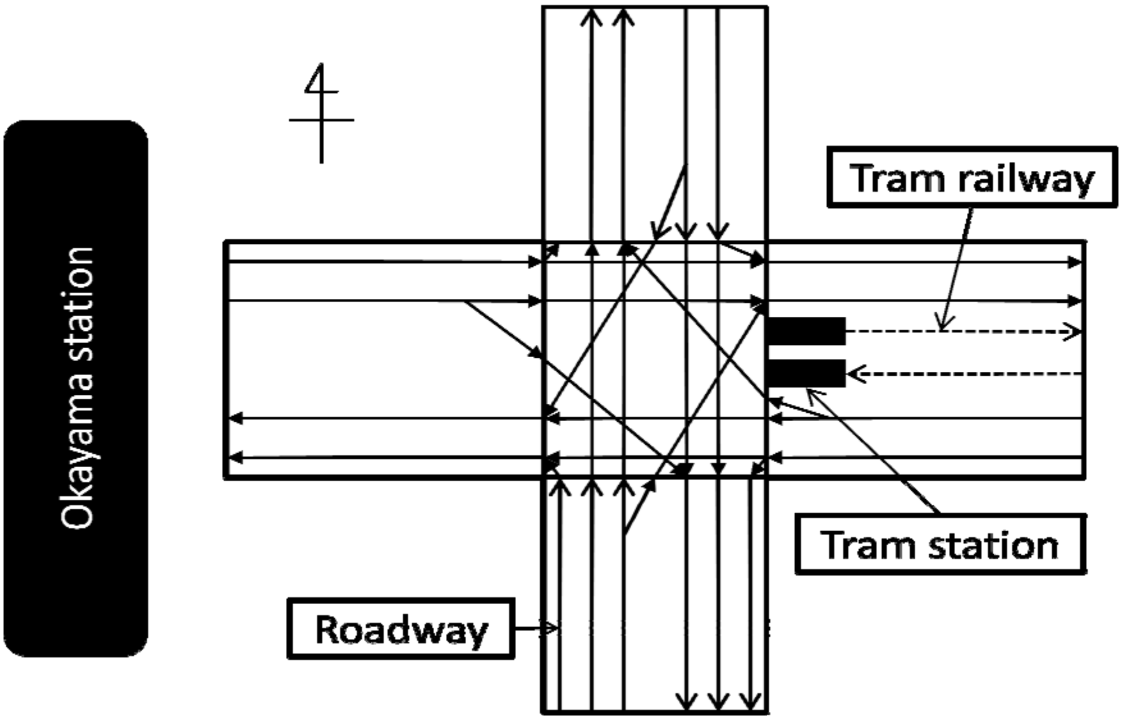

Figure 2 Intersection network before extension

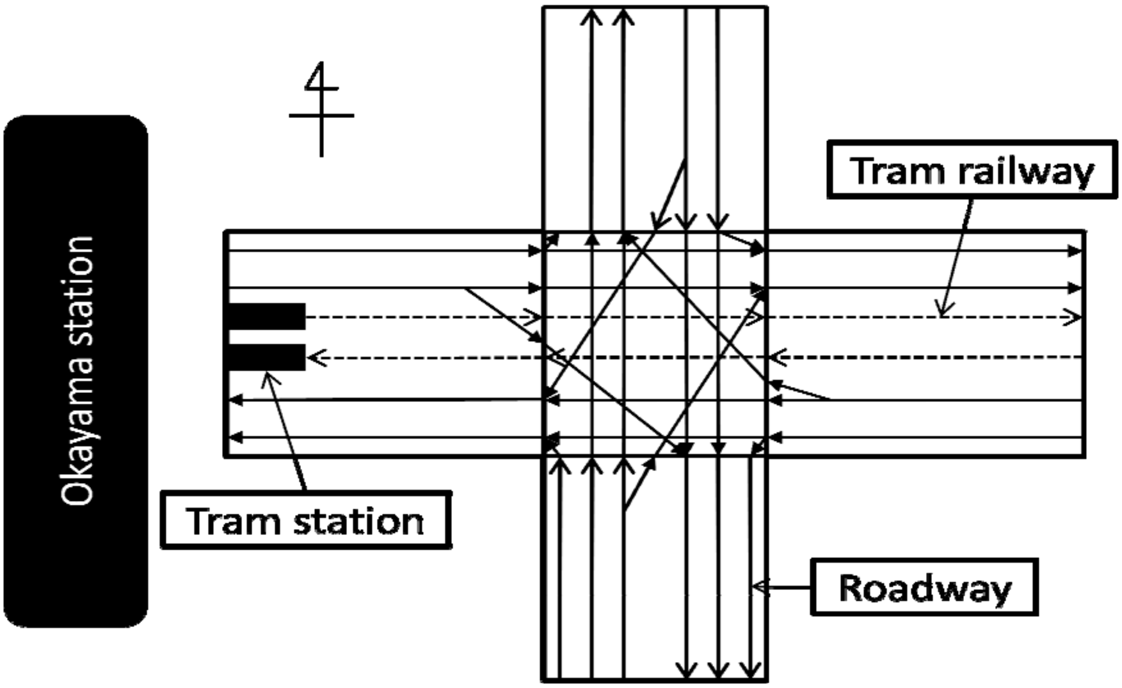

Figure 3 Intersection network after extension

Simulation conditions

A range of simulation is about 3 km square including 1 km square area which contains center of the city and there are about 300 intersections.
The traffic volumes and O-D are decided by the result of social traffic experiment which is held during 17th (Sat) – 20th (Tue) February, 2001 period.
One of the biggest differences between the social traffic experiments and simulation is there is no vehicle and no pedestrian on the street at time step zero in the simulation world. Thus the beginning of simulation results doesn't have meaningful insights. And so we installed counters at major intersections to count the number of run thorough vehicles. When the figures of counters nearly meet the result of social traffic experiment, then we set t = 0. From this moment, we start virtual social traffic experiments for an hour. We pay attentions for the volume of traffic flows during the experiments to avoid gaps against the social traffic experiment conditions. Some major traffic lights data were provided by Okayama Prefecture Police and other traffic lights are assigned appropriate data. Although, collecting more traffic lights data is necessary for more precise simulation and this will be an important subject of future investigations.

Result

The results of simulations are shown below. The number of inflow to the intersection from south side in time series is shown in Figure 4, passing time is shown in Figure 5. Both figures compare before extension and after extension. Compare to before extension, the number of inflow vehicles decrease 7 % per hour but properties of traffic flows are considered almost same. Also the results of inflow from west side are shown in Figure 6 and Figure 7. Total volume of inflow vehicles from west side decline only eight vehicles and passing time for after extension doesn't show large shift from before extension.

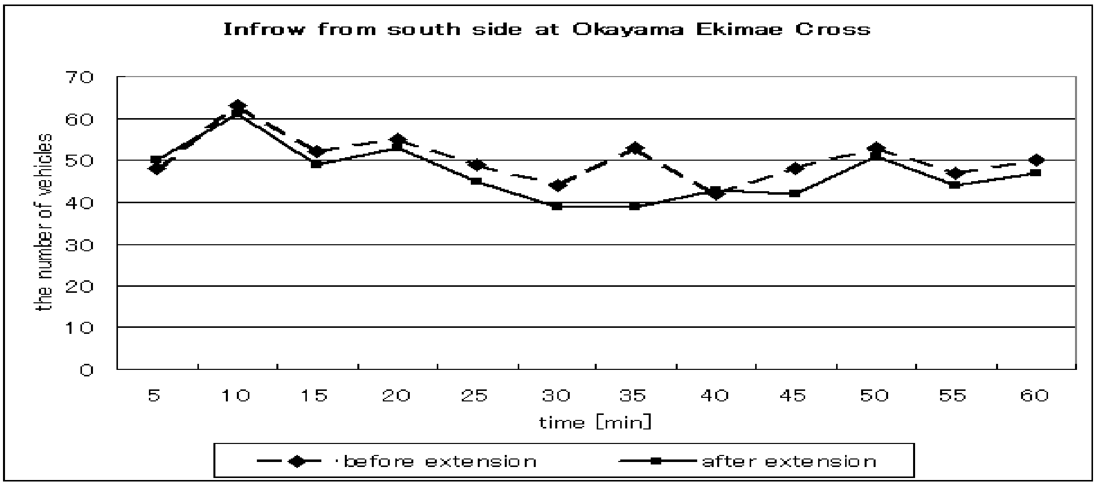

Figure 4 Comparison of the number of passing vehicles in time series (inflow from south side)

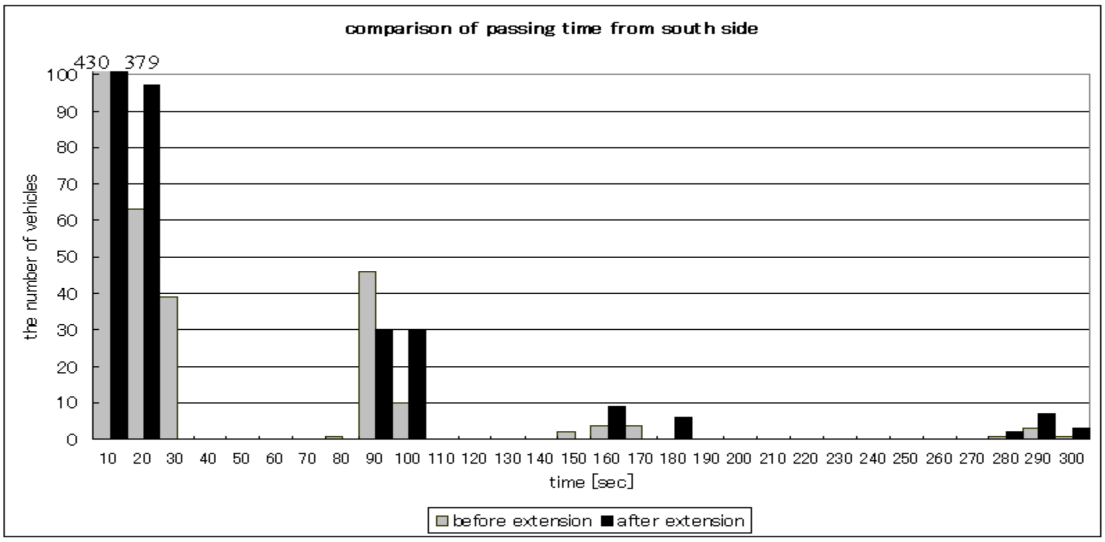

Figure 5 Comparison of passing time from south side

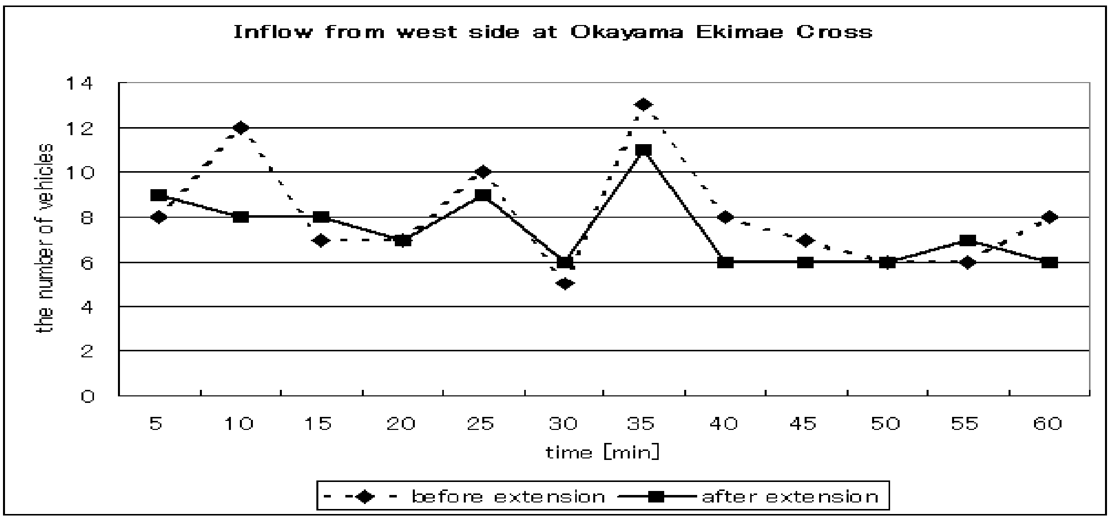

Figure 6 Comparison of the number of passing vehicles in time series (inflow from west side)

Figure 7 Comparison of passing time from west side

INVESTMENT EVALUATION FOR TRAM RAILWAY EXTENSION

Net Present Value

Net present value is the most widely used conventional evaluation tool for large scale investments. NPV method discounts estimating free cash flows by weighted average cost of capital, then subtract needful present value of investment costs. If the result is bigger than zero this investment plan will carry out and if less than zero this project will not carry out. This is the principal of NPV evaluation method.

The problem of NPV method is lack of flexibilities. Normally, decision makers have some flexible options like abandonments, shrinking, expanding or extend options. Decision makers consider these options in their minds and make appropriate decisions. Therefore evaluation methods should have an ability to evaluate these option values to clarify the real investment values but NPV method doesn't support this part. For this, NPV method sometimes underestimates the investment values. Many professional practical persons know this structural problem. Thus, it is not a surprise if they decide to carry on new investment projects even the result of NPV tells them negative numbers.

Real Option Approach

Real option approach has introduced in the advanced companies since around 1990s instead of NPV method. The concept and philosophy of real option approach are derived from financial engineering which is mainly developed to find out the appropriate prices and indexes at the stock market, the bond market and the commodity market. Real option adopted financial derivative technologies to analyze real investments more flexible than NPV method

There are two major calculation methods to calculate option value, one is a famous Black-Scholes model and another is a binominal model. We introduced the binominal model instead of Black-Scholes model, because of following main reasons.

- The option may be exercised only at maturity (so-called European option)
- The exercise price is known and constant
- The option is contingent on a single underlying risky asset

It is still possible to use the Black-Scholes model but most real options problems require analysis that is capable of relaxing one or more of the standard Black-Scholes assumptions.

Economic loss and time loss due to the traffic congestions

An evaluation for loss due to the traffic congestions is calculated by following equation.

Each vehicle economic loss = (Actual travel time – standard travel time) * Value of time

\- Equation 1

The standard travel time means that the travel time without traffic congestions. Generally, the standard travel times is assigned 10 percentage cumulative numbers from the fastest travel times. The time value by car model in Japan is shown in the table 1. And, the average numbers of passengers by car models in Japan are 1.33 persons in the auto and 17.59 peoples in the bus.

Table 1– Time value by car model in Japan [unit: yen / (vehicle * min)]

Car model	Weekday	Weekend
Auto	56	84
Bus	496	744
Small cargo	90	90
Cargo	101	101

In this study, we defined the volume of traffic flows which are considered and decided by the social experiment in 2001 as a standard model. Then, we estimated the average trip time of each vehicle by calculating the MATES 10 times and defined it as the standard travel time. Under these assumptions, we calculated the traffic flows after tram railway extensions. In this case, we assumed that the number of inflow vehicles on the roads which have tram railway would decrease caused by an increase of the number of tram passengers. Therefore, we introduced some restrictions for the behaviour of some vehicles and calculated as the after tram railway extension model.

Estimation of the number of passengers after extension

How many passengers will increase (or decrease) after 200 meters tram railway extension? This question is very important for our simulation but it is also a very complicated question to expect. There, we got some ideas from other example. In 1998, the tram railways in Toyohashi City, Aichi Prefecture were extended to the central station in Toyohashi City. The length of this extension was about 150 meters and it had some similarities with the case of Okayama City.

In case of Toyohashi City, the number of tram passengers after extension grew from 3.13 million per year to 3.30 million per year (5.4 percent increased). We assumed the same scenario will happen in case of Okayama and we presumed two possible scenarios, one is 5 percentage of passengers will increase and another is 10 percent increase as a good case. Table 2 explains how many passengers will increase in weekdays after extension with each scenario. If five percent increase will be achieved, 485 passengers will be increased a day and we assumed 200 passengers out of 485 new tram passengers will increase during at the peak of the rush. 200 passengers increase means a decrease of 136 vehicles on the roads around the tram railways. In the same way, 274 vehicles will be decreased in the case of 10 percent scenario.

Table 2 – The number of average weekday's daily passengers

Current average passengers a day	5 % increased	10 % increased
9700	10185 (+485)	10670 (+970)

Estimation of the improvement of economic loss by extension

To realize the most possible scenario, we constructed a new path near the tram railway terminal station and about 136 vehicles were given that path as their goal intersection and also did some adjustment the traffic flows around the tram railways. Then we did 10 times calculation by MATES for each scenario and measured the standard travel time. Table 3 shows the result of calculations and the differences with average travel time are defined as the improvement time of traffic congestions. This improvement time can convert to the improvement of economic loss with table 1 elements.

Fifteen seconds improvement is considered that it doesn't have a significant impact for people. Therefore, we proceed to the further discussion with 10 percentage increased scenario.

Table 3 – Result of calculations

	Total number of vehicles	Vehicles which can be reached their goal	Average travel time [sec]
Before extension	28,571	6,287	1,623 (0)
After extension (5 % increased)	28,589	6,216	1,608 (-15)
After extension (10% increased)	28,088	6,322	1,542 (-81)

INVESTMENT ANALYSIS BY INVESTORS

Investor: Okayama Electric Tramway Co Ltd.

If tram operator Okayama Electric Tramway decides to invest this extension plan by itself, the valuation is lead like following. In case of 10 percentage increase scenario, passengers will increase 970 per weekday and the total increased annual revenue from tram railway operation can be calculated by below equation.

$$102.7[Yen] \times 970\ [passengers] \times 250\ [days] = 24{,}904{,}750\ [Yen]$$

\- Equation 2

We assume this project term as five years, thus the present value (PV_5) of this extension project is given in equation 2.

$$PV_5 = \sum_{t=1}^{n} \frac{CF_t}{\left(1+r_f\right)^t} = \sum_{t=1}^{5} \frac{2490}{(1+0.015)^t} = 119{,}080{,}000\ [Yen]$$

\- Equation 3

CF: cash flow, r_f: risk free interest rate = 1.5 %

The amount of expected investment price (*I*) is 600,000,000 yen for this railway extension project and in case of Toyohashi City, a third of investment was subsidized by the Japanese government. It is commonly believed that the same scheme will be applied to Okayama City case. Therefore, 200,000,000 yen will be subsidized by the government and Okayama Electric Tramway will be considered to invest 400,000,000 yen by itself. NPV_5 can be lead by following equation.

$$NPV_5 = PV_5 - I = 119{,}080{,}000 - 400{,}000{,}000 = -280{,}920{,}000\ [Yen]$$

\- Equation 4

Thus, Okayama Electric Tramway doesn't decide to invest the project under these conditions.

Investors: Okayama Prefecture and Okayama City

Next case we assume this investment will be done by Okayama Prefecture and Okayama City. As an investor of this project, there is a big position difference between Okayama Electric Tramway and the regional governments. The tramway operator has opportunities for gaining the profit from this kind of investment but the regional governments cannot obtain the economic profit directly from the project. Increase of revenue only contributes to the operator's annual operating performance.

What is the profit for the regional governments from this investment? The profits of the regional governments must be the profits for the citizens in that region. Therefore, we assume that the improvement of economic loss due to traffic congestion can be considered as the profit from this tram railway extension investment for the regional governments. As previously mentioned, every year 120,000,000 Yen will be recovered if 10 percentage of tram passengers increased. This price is considered as the profit for Okayama Prefecture and Okayama City. The term of the project is five years and the present value (PV_5) and NPV_5 are shown below.

$$PV_5 = \sum_{i=1}^{5} \frac{120{,}000{,}000}{(1+0.015)^t} = 573{,}920{,}000\ [Yen]$$

- Equation 5

$$NPV_5 = PV_5 - I = 573{,}920{,}000 - 400{,}000{,}000 = 173{,}920{,}000\ [Yen]$$

- Equation 6

The value of the NPV_5 is bigger than zero thus this project is considered as there is an economic rationality to invest.

Project value: In case of there are options

At present, it is uncertain that tram railway extension will lead to the improvement of the traffic congestions or not. There, let's assume if the Okayama Prefectural government and the Okayama City government have a put option against the operator if the traffic congestions will not be improved.
This put option is only valid for if the annual value of improvement of traffic congestions lowers than 200,000,000 Yen for the project duration or five years. In such case, they can exercise the put option against Okayama Electric Tramway and charge a half of total investment value (200,000,000 Yen). The details of variable numbers are shown below Table 4.

Table 4 – Variable numbers for calculations

NPV	573,920,000 [Yen]	Annual time step	1 [step]
Exercise price	200,000,000 [Yen]	Risk free interest rate	1.5 [%]
Option duration	5 [years]	Up movement	1.5
Standard deviation of the revenue	40 [%]	Down movement	0.67

Under the best case, this project value will meet 1,290,000,000 Yen after five years but it may end up with only 23,000,000 Yen under the worst scenario (see Figure 8). Figure 9 shows how it is evaluated and explicated if the regional governments have the put option against the operator. The rectangles with broken lines mean that the put option is exercised. Theoretically, any conditions after the rectangle *F*, the put options are always exercised. And a price of stage *A* (242,000,000 Yen) shows the value of the investment with the put option.
The project value difference between with the put option and without the put option is 72,000,000 Yen and this price is considered as a put option value. Consequently, this investment became more attractive for the regional governments.

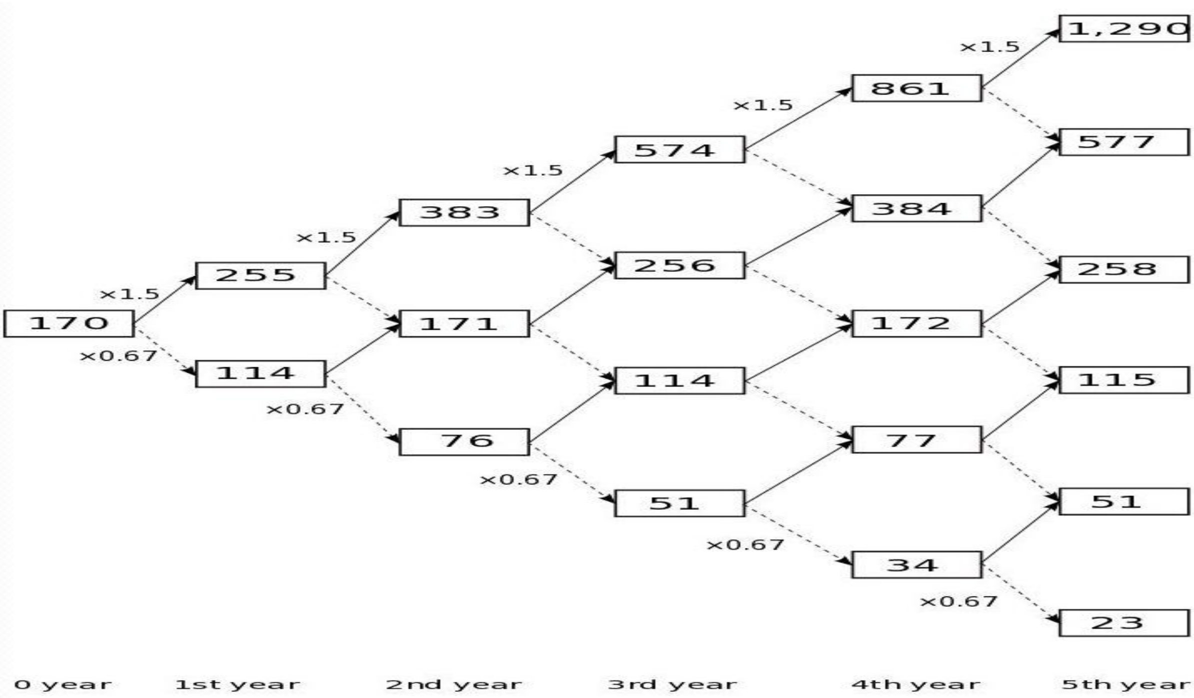

Figure 8 Event tree for asset value transition (unit: million Yen)

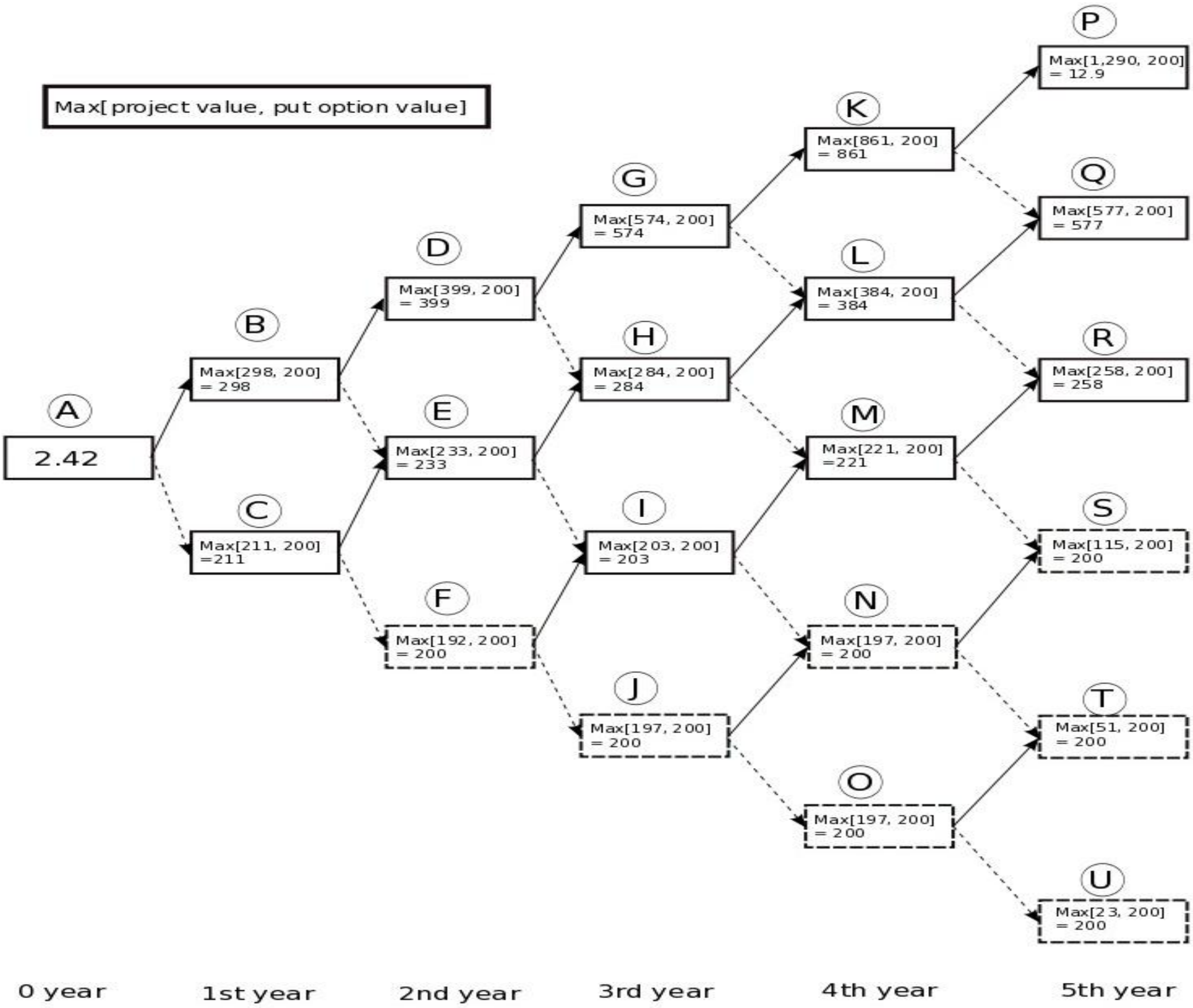

Figure 9 Event value of the project value in mind option value (unit: million Yen)

CONCLUSIONS

In this paper we discussed the possibility of tram railway extension in Okayama City. We analyzed traffic problems with MATES and also analyzed investments matter with results from MATES and real option approach. Consequently, tram railway extension which runs straight through the intersection is considered that not effects significant impact on traffic flows around the station.

And we also showed, in case of Okayama Prefecture and Okayama City bear the investment expense, if Okayama Electric Tramway Co Ltd. issued the put option to the regional governments, both stakeholders can share responsibility for this tram railway extension plan. This option only can be exercised when the project value become smaller than exercise price of the option. Therefore, tram operator is motivated to increase the number of passengers from vehicle users and consequently these continuous marketing efforts will lead to improve the heavy traffic congestions. Fig 10 represents their relationships and they can cooperate together to realize more convenient and more comfortable mobility environment under this framework.

Finally, we need many efforts to calculate a standard deviation of the revenue more precise when we execute real option analysis. Monte Carlo approach or historical data analysis approach have been proposed but there is no decisive methods have built. The development of this field is very important because we always emphasis on quantitative and precise analysis.

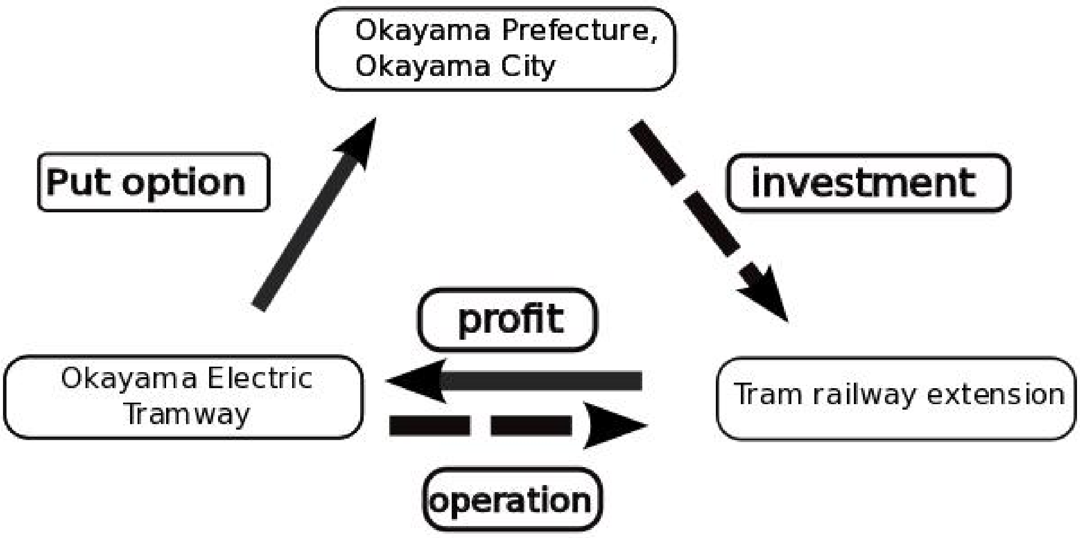

Figure 10 The relationship between the regional governments and the tram operator

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