DEVELOPMENT OF BICYCLING SIMULATOR FOR ANALYSIS OF TRAFFIC SAFETY AND FLOW

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ABSTRACT

Cycling on sidewalk is very popular in Japan due to the amendment of traffic law in 1970s. Entering the aging society, pedestrians' safety on sidewalk is being a crucial matter to be solved. In response to this problem, bicycling on carriageways is being encouraged especially in central districts. However, we don't have the detailed design guideline of bicycle facilities, which is available for various attributes or purposes of cyclists and is also adequately-considered for vehicle drivers. In addition, because average cyclists also believe that they ride bicycle more safely and in relief on sidewalks than on carriageways, the bicycle facilities on carriageways is likely to be hardly used. Therefore, we need to examine various road designs and traffic situations to develop better bicycle facilities, but experiments by actual running are often dangerous. In this study, we developed a new cycling simulator ("Morics") which is available for analysis on the safety and the influence to the other modes.

Keywords: cycling simulator, weaving and leaning, traffic safety analysis

BACKGROUND AND OBJECTIVES

Background -Current Situation of Bicycle Traffic in Japan-

Bicycles have a great role of economic, effective and eco-friendly modes all over the world. Figure 1 shows the modal share of bicycle in some cities in Japan and EU countries. The modal share of bicycles in Osaka is about 25%, and one in Tokyo is about 14%, and that in

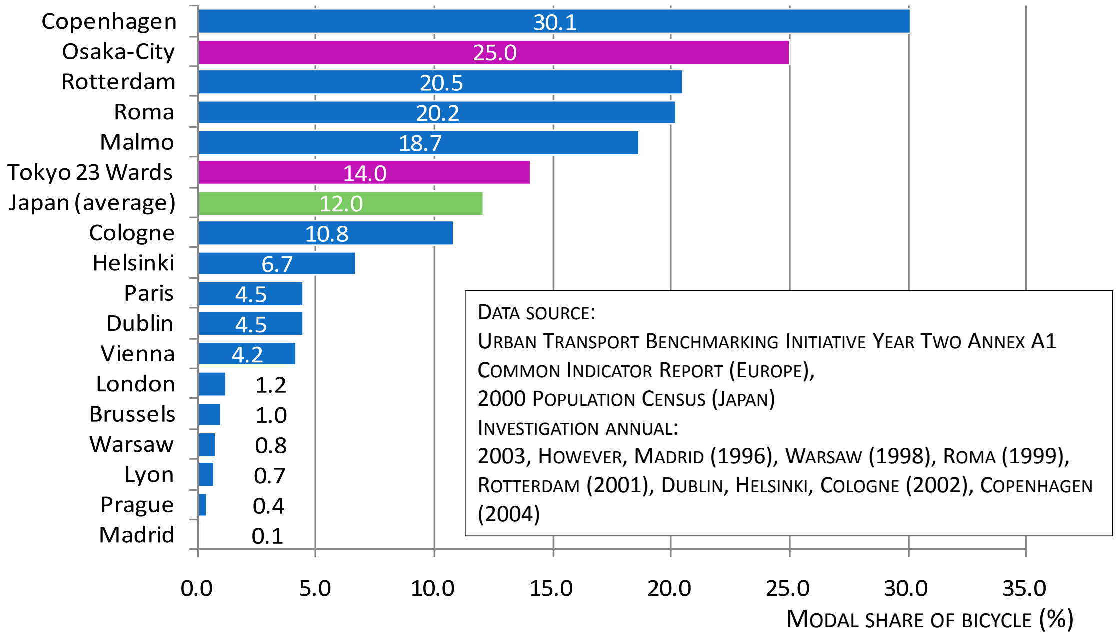

Figure 1 International comparison of modal share of bicycles

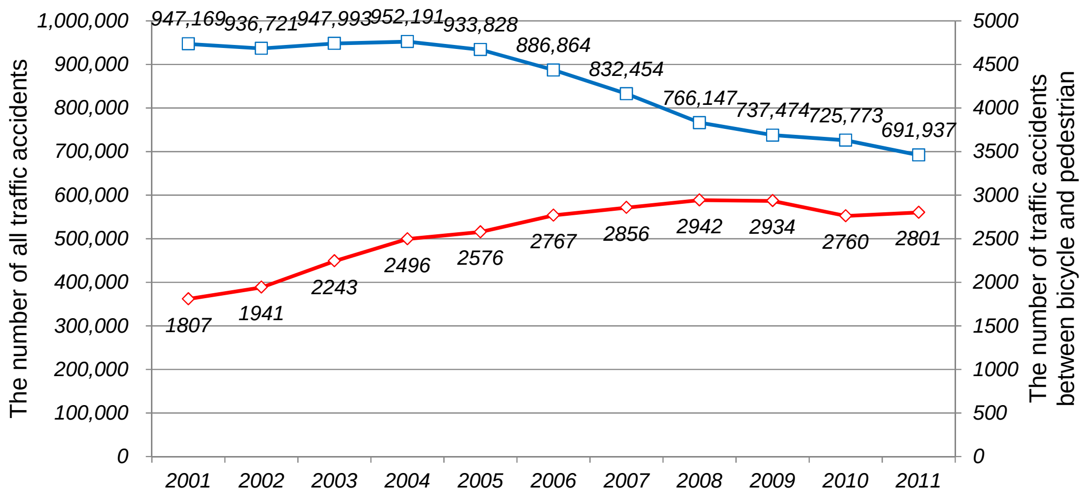

Figure 2 Number of accidents of all traffic (blue) and between bicycles and pedestrians (red)

Japan is much higher than that in many EU countries. In the average in Japan, we have one bicycle per 1.5 people and we can say that Japan is one of the biggest bicycle country. In Tokyo, there are about 8.4 million bicycles and modal share of bicycle in Tokyo 23 Wards is about 10%. In addition, 18% of rail users access to the station by bicycles.

One of the reasons why we have so many bicycles is said that bikers are permitted to ride bicycles on sidewalks in Japan. In principal, people ride bicycles on carriageways in Japan same as other countries, but almost bikers are on sidewalks. Because they believe that bicycling on sidewalks is safer than on carriageways.

It sounds safe that bicycle is on the sidewalk, but how will the situation affect the safety of bicycle? Figure 2 shows the number of all traffic accidents and ones between bicycles and pedestrian last 10 years. The number of all traffic accidents is
coming down, but the number of accidents between bicycles and pedestrian has increased.

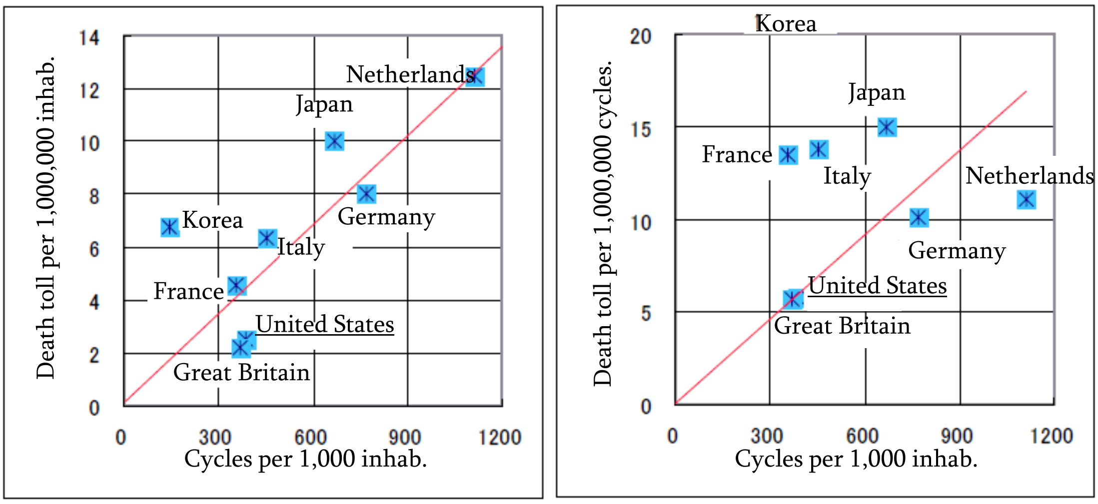

Figure 3 International Comparison of Death Toll during Bicycling

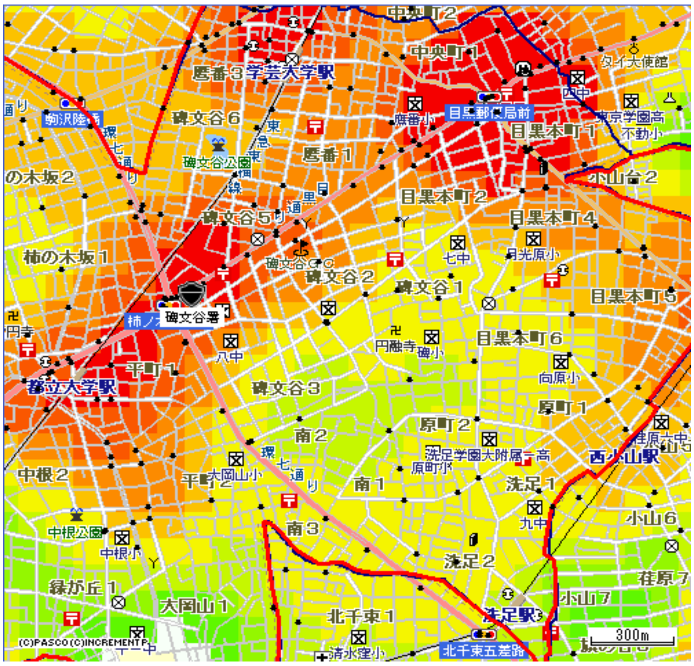

Figure 4 Places of bicycle accidents Metropolitan Police Department (2008)

It's dangerous situation not only for pedestrians but also for cyclists themselves. Figure 3 shows the relationship between bicycles possession and the death toll. It seems that the Japanese situation, cycling on sidewalks is safer than the other countries where people bicycle on roadway, but as you can see the reverse is true. Moreover, the map on the left side shows the density of bicycle accidents in 2008 in Figure 4. The higher number of accidents had occurred in the red zone and each black dots are showing the place of accidents. You can recognize that the bicycle accidents occur everywhere.

Because of them, we can say that bicycling on sidewalks is not always safe.

In accord with the situation, the guideline for development of safe and comfortable bicycle facilities by MLITT (Ministry of Land, Infrastructure, Transport and Tourism) and National

Police Agent was published in last November. In this guideline, there's 3 important points for cycling on carriageway in Japan shown in below.
1) "Reinforcement of the rule of cycling on carriageways"
We have to keep left on carriageway as a general rule to protect the pedestrian's safety and make it clear where the bicycle is passing.
2) "Appropriate reallocation of road spaces"
There was no guidelines about bicycle lanes, so the guideline shows some design standard as a fundamental form.
3) "Plan for bicycle route network"
We have to develop a recognition of "Bicycle is Vehicle" for both cyclists and car drivers and promote cycling on carriageway by a sense of safety.
As I mentioned, it's not always safe that people ride bicycle on sidewalks in two-ways. So that bicycle traffic becomes safer, we need to analyze cyclist's behavior and evaluate the bicycle facilities' design. But as you know, actual running experiment is dangerous especially about accident analysis.

Existing Cycling Simulator

There are some cycling simulators around the world. But the role of Cycling Simulator (CS) for making use of analysis and evaluation of safety and comfort during bicycling. There are some existing CS, but they can be used only for educational purposes, in other words, driving instruction or learning traffic rules. The reason why they can't be used for safety analysis is that can express their leaning and unintended weaving which are related to the safety. So, in order to use the CS for an educational, practical and research tool about bicycle safely and comfortably in urban city, we need to consider bicycle behavior and riding feelings of the CS.
If the CS for the educational purpose is developed, we can improve the risk prediction ability and safety awareness of the use of bicycle and we can happily learn traffic rules and manners by experiencing safely possible hazards when driving a bicycle. And if the CS for the practical use is developed, we can evaluate bicycle facilities by it more inexpensively than by conducting any pilot program. Moreover, if the CS for the research is developed, we can safely get the data which is difficult to get on the actural driving experiment, for exmple, accident data. These three aspects are the characteristics of CS which we need to develop.

Objectives

As I mentioned, it's not always safe that people ride bicycle on sidewalks. So that bicycle traffic becomes safer, we need to analyze cyclist's behavior and evaluate the bicycle facilities' design. Actual running experiment is dangerous especially about accident analysis. And we have few data about bicycle safety analysis using the accident data in Japan.
So we need cycling simulator which can get data about bicycle behavior safely, and which can design and evaluate bicycle facilities. That is the objectives of our study, in other words, to develop the CS for traffic safety analysis.

In this study, we developed the cycling simulator which can express the leaning and weaving behavior during cycling. At first, we indicated the factors which need for the evaluation of safety and road design. Secondly, we showed the difference between the system of the Cycling Simulator and the Driving Simulator "MOVIC-T4" which we make a reference to develop. After we showed the input and output of the Cycling Simulator, we revealed the resolutions and challenging issues for completing the development.

ADVANTAGE AND CONCEPT OF OUR CYCLING SIMULATOR

Requirement and Advantage of Our Cycling Simulator

The requirement and advantages of our CS depend on the purpose of use. Our Cycling Simulator has 2 purpose of use, that is, the bicycle accident analysis and the design and evaluation of bicycle facilities.
At first, for bicycle accident analysis, it is possible to get the multiple and detailed data that is difficult to get in an actual running experiment and analyze this data. For example, the risk of accidents of interactions between bicycles and cars on carriageways is not obvious at present because of few people ride bicycles on the carriageways in Japan.
And secondly, for bicycle facilities' design and evaluation, it is possible to design and evaluate the “network-wide” bicycle facilities. For example, the evaluation of bicycle facilities using the CS is much cheaper and faster than constructing them in the real world. Moreover, the evaluation of bicycle facilities is actually difficult because it depends on the surrounding traffic situation and they are difficult to maintain, improve and re-construct in the real world.

Concept of Our Cycling Simulator

Our CS system was developed with 3 concepts shown below.
1) It is possible to set and use subjects' own bicycle. In Japan, people ride various kinds of bicycles from light cycles to sports bikes. So they can have more real riding feelings when they ride own bicycles on the CS.
2) Virtual environment is expressed with the Head-Mounted Display (HMD). Because if subjects wear HMD, they can see everywhere with the panoramic 3D images when looking around by shaking your head, so they can ride a bicycle in the more immersive virtual environment. Moreover, it is said that a rider of sports bike tends to look lower side and a rider of light cycle tends to look forward. The various view behavior can be covered with the HMD.
3) It is compact and simple structure. The CS which is easy to move can be used anywhere and be useful as a research tool.

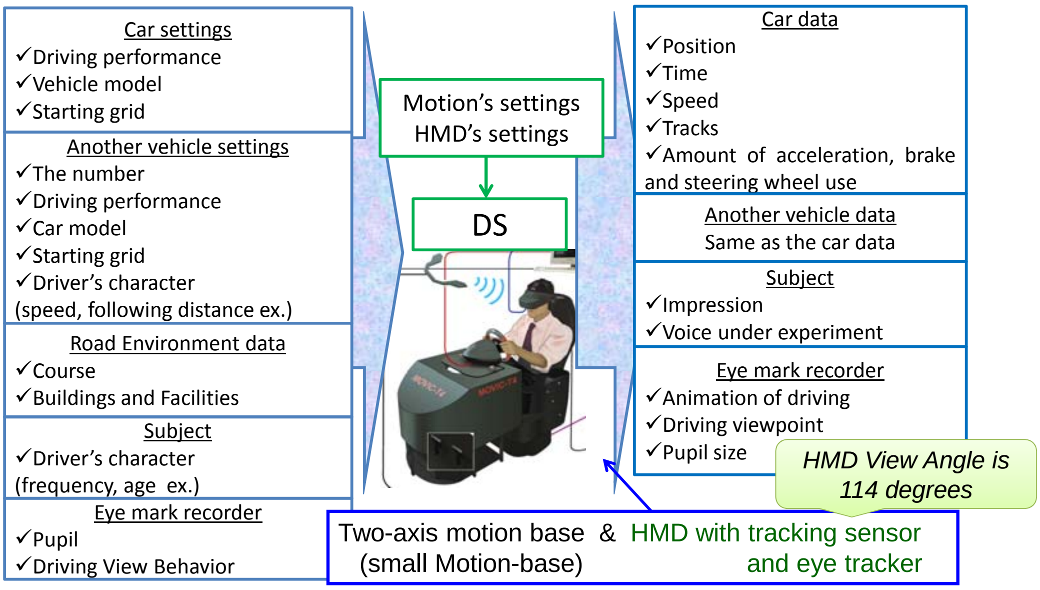

Figure 5 Outline of System of Driving Simulator "MOVIC-T4"

OVERVIEW SYSTEM OF OUR CYCLING SIMULATOR

Making a Reference of Driving Simulator's System

A compact driving simulator "MOVIC-T4" (DS) was developed between 2002 and 2005 in our laboratory, and we made a reference of it to develop the CS. "MOVIC-T4" has 2-axis motion base for riders' feelings and the HMD with tracking sensor for creating panoramic virtual space. And the AI cars can be generated up to 60 which change their behavior, for example, avoid to conflict and so on. The input and the output of the system in "MOVIC-T4" is shown in Figure 5. We can set up "Car characteristics", "Other vehicles' characteristics", "Data of road environment" on the DS program. In addition, we can equip the eye tracking sensor in the HMD.

We make a reference of its system. But developing cycling simulator is more complicated than the development of driving simulator. Because leaning and weaving have to be considered on the CS.

Input and Output of Our Cycling Simulator

With making a reference of "MOVIC-T4", the outline of the CS system is developed shown in Figure 6. As I mentioned before, "weaving angle" and "leaning angle" need to be added to the output and thus we need to input "pedal force", and "handling force". So the output data are position, speed, acceleration and braking of the subjects and the other vehicles, leaning angle and traveling direction including weaving angle at 0.1-0.5 second interval. And we can also get the eye-tracking data of the subject.

And 2 subjects can drive in the same virtual reality space at the same time by using CS and DS. If do so, we can observe interactive driving behavior for accident analysis.

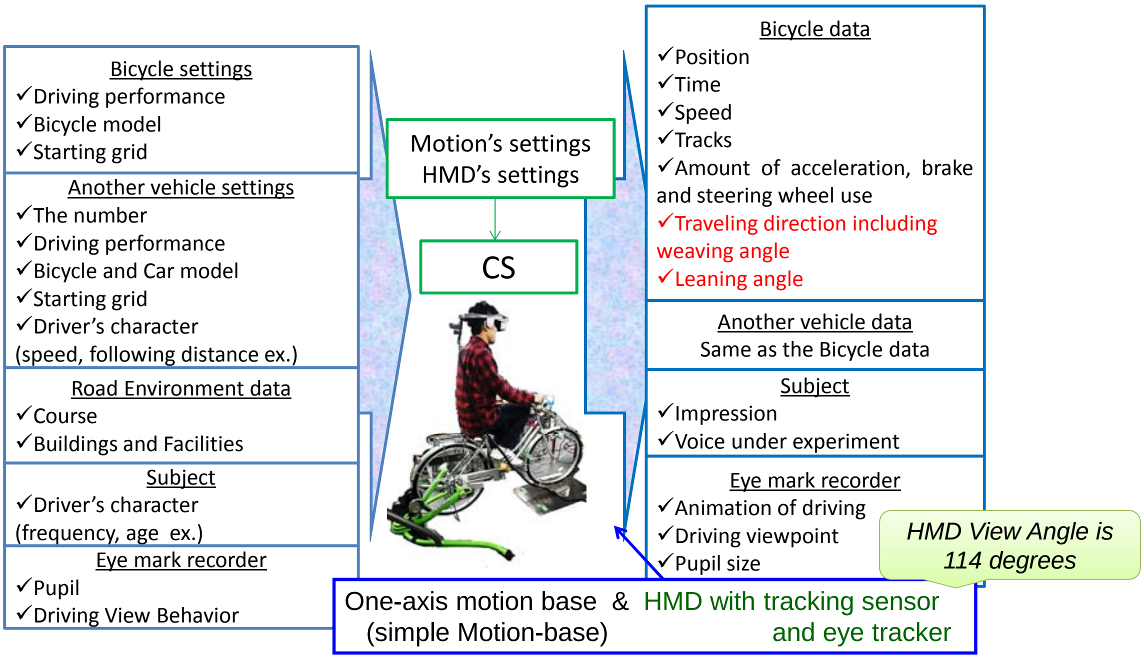

Figure 6 Outline of System of Cycling Simulator

Overview Structure of Our Cycling Simulator

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Basically it is consisting the load generator, the actuator, and a bicycle. The load generator can change its load in real time, so reaction force of pedaling can be considered at any speed or road conditions because pedal force is depend on the load generator. And the actuator move up and down, so the height different between sidewalk and carriageway, deceleration, slope, and shock are expressed by the actuator's up-and-down motion. Moreover for the comfort of subjects, the supporting system of the HMD is equipped because it is poor balanced and heavy weighted.

Input/Output about Weaving and Leaning Behavior on Cycling Simulator

In this section, we described the system of the unintended weaving and leaning behavior on cycling simulator in the simplest situation –going straight. We consider their behavior as important points for safety analysis of cycling, because a bicycle on the bicycle on the Cycling Simulator stops and it is too easy to turn a handle.

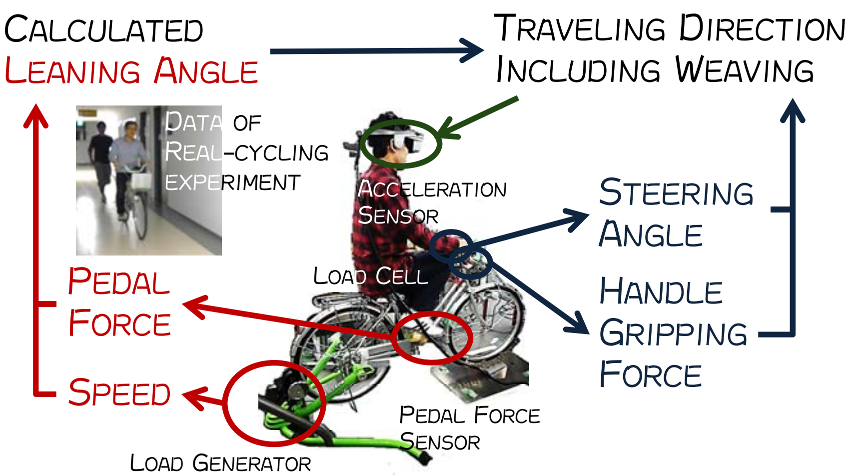

Figure 7 System of Calculating Traveling Direction Including Weaving Angle

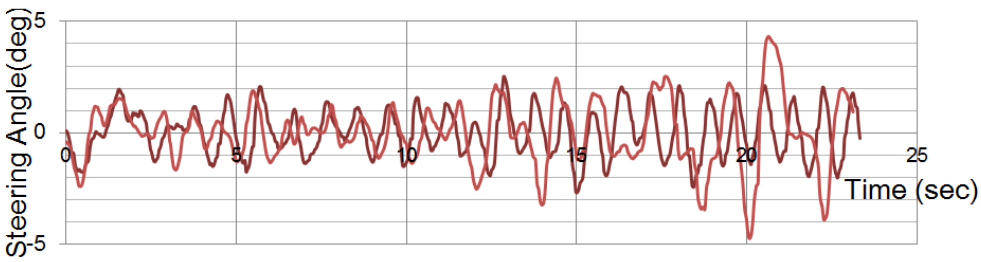

Figure 8 Steering Angle in riding CS (positive; turning right, negative; turning left)

In term of leaning behavior, we assume that it depends on 2 factors -the balance of weight both a bicycle and a rider, and the speed. Moreover in going straight, the balance of weight is related to the balance of the each pedal force, because a rider doesn't need to move. We conducted the experiments in the real world using the real bicycle with some sensors and observed the pedal forces, the speed, the steering angle, and the handle gripping force which operates the traveling direction. And using the result, we made the model of leaning angle by the pedal forces, the speed.

Pedal force and speed are observed on our Cycling Simulator, and the leaning angle is calculated which was modeled by the real-cycling experiment data I explained. At once, the steering angle and handle gripping force are observed. Finally we can get the traveling direction data including weaving angle and it is feed back to the screen on the HMD.

It's very simple structure by using sensors.

Moreover for the reality of rider's feeling, A Bicycle can lean a little by the rubber put between the plates of the load generator which a bicycle is attached.

We conducted the validation with 3 male students. We observed the steering angle and the traveling direction including weaving when a subject rides on the Cycling Simulator and compared it with the data in actual running. The course is a midblock of roadway and a subject rode and went straight about 15 seconds. As the result, the steering angle of the CS (red line in Figure 8) was almost same trajectory as the one of actual running (brown line in Figure 8). And 3 male subjects answered that they could ride the CS without any comfort compared to cycling in real world.

Table 1 Challenging Issue of Development the CS

	Challenging Issue	Methodology
Bicycle Itself	Speed	Load generator
	Leaning	Modeling
	Steering	Modeling
	Pedaling	Pedal Force
	Braking	Pedal Force + Load generator
Riding Feeling	Sound	Head Phone
	Wind pressure	Fan & Head Phone
	Deceleration/Difference/ Slope/Shock	Actuator's Up-and-Down motion
	Leaning	On HMD screen
	Steering	On HMD screen
	HMD	View angle is 114 degrees Possible to see Panoramic View

Challenging Issue of Development

We have also some improvableness for accident analysis.
At first, learning bicycle is depend on rider's balance of weight, so leaning behavior will be calculated with higher accuracy. Secondly, braking can consider only at the rear wheels, so braking will be observed with the both wheels. And thirdly, steering is calculated at the stopped state and it's easy to turn, so reaction force of steering has been considered.
Table 1 shows the challenging issues of development of our Cycling Simulator. As I already explained, the leaning and steering behavior's reality need to be improved. Moreover, we will consider sound and wind pressure especially during bicycles on carriageways by fan and headphone.

CONCLUSIONS AND FUTURE WORKS

In this study, we showed the basic structure and the system of the Cycling Simulator which can use for safety analysis and evaluation of bicycle facilities. The conclusions and future worksare shown below;

1. Our Cycling Simulator for safety analysis has 3 point, "possible to set your own bicycle", "virtual environment is expressed with Head-Mounted Display", and "Conpact and Simple".

2. It is expected that the development of our Cycling Simulator has the possibility to contribute to the bicycle accident analysis and the evaluation of bicycle facilities because of consideration about weaving and leaning behavior.

3. We can express the weaving and leaning angle using the pedal force, the speed, and the steering angle and the simple system can improve the .

4. Our CS needs more reality, especially for steering, leaning of a bicycle.

5. We will have been challenging to make new models and devices to improve our CS.

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