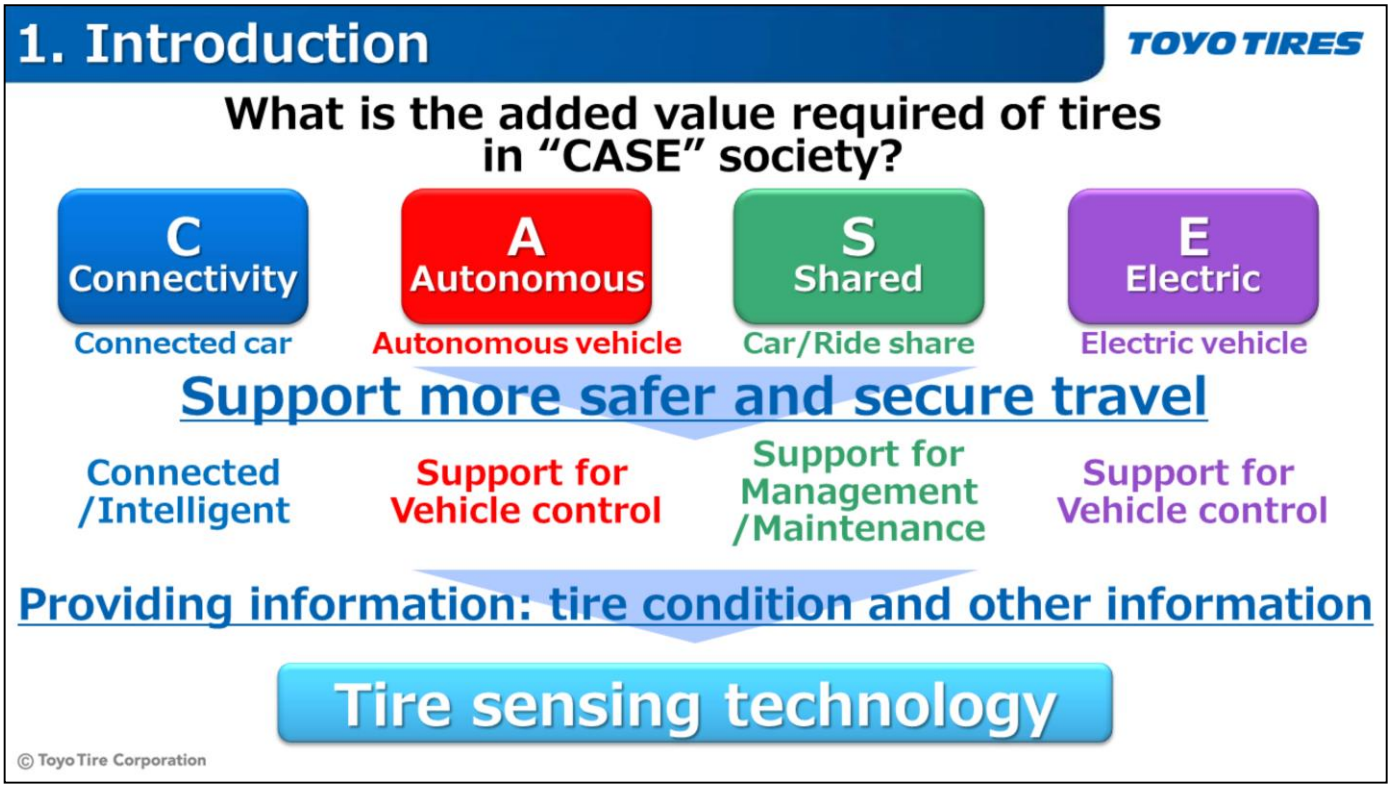
TOYO TIRES

Introduction of the development technology

Toyo Tire's
Tire Sensing Technology concept

February 7, 2020

Toyo Tire Corporation 75 ANNIVERSARY



The automotive industry today is said to be entering a major transition phase of the kind that happens just once a century.

The changes involved are known as CASE: Connectivity, Autonomous driving, Shared and Services and Electrification.

These technologies lead to the connected car, the autonomous vehicle, car/ride sharing services and the electric vehicle (EV).

Through the combination of these technologies, dramatic changes are taking place in the industry and society.

In the face of these rapid changes in the next-generation mobility-based society, we believe that our product, the tire, must likewise undergo change.

What then is the added value needed for the tire in a CASE society undergoing revolutionary change?

We believe it is "support for safer and more secure driving."

For this reason, the car tire needs the following, when viewed from the four CASE perspectives.

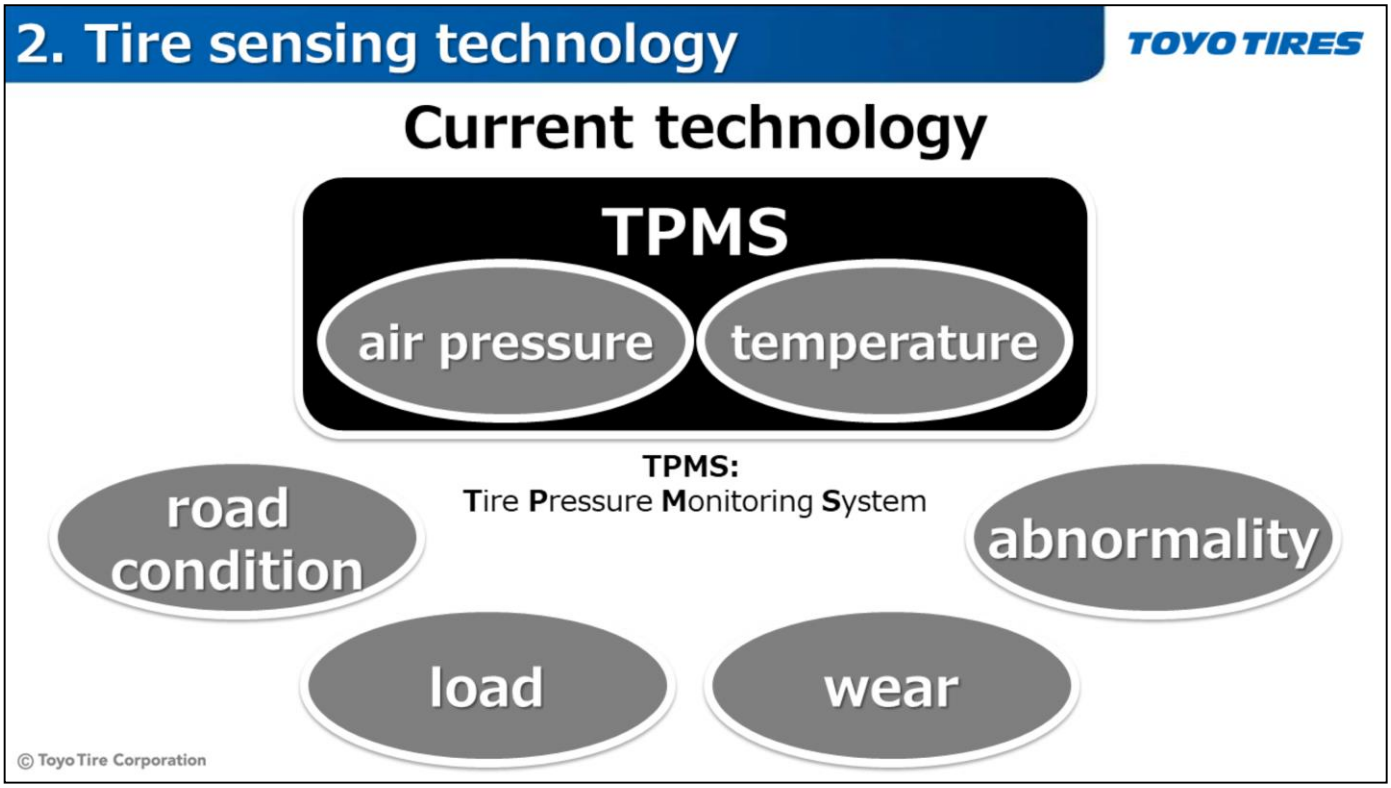
Connectivity: Connected and intelligent tires through data communication

Autonomous driving and electrification: Support for advanced vehicle control

Shared and Services: Support for vehicle management and maintenance

The keyword (added value) shared in common by these requirements is "supplying tire information" to the vehicle, the user and the management company.

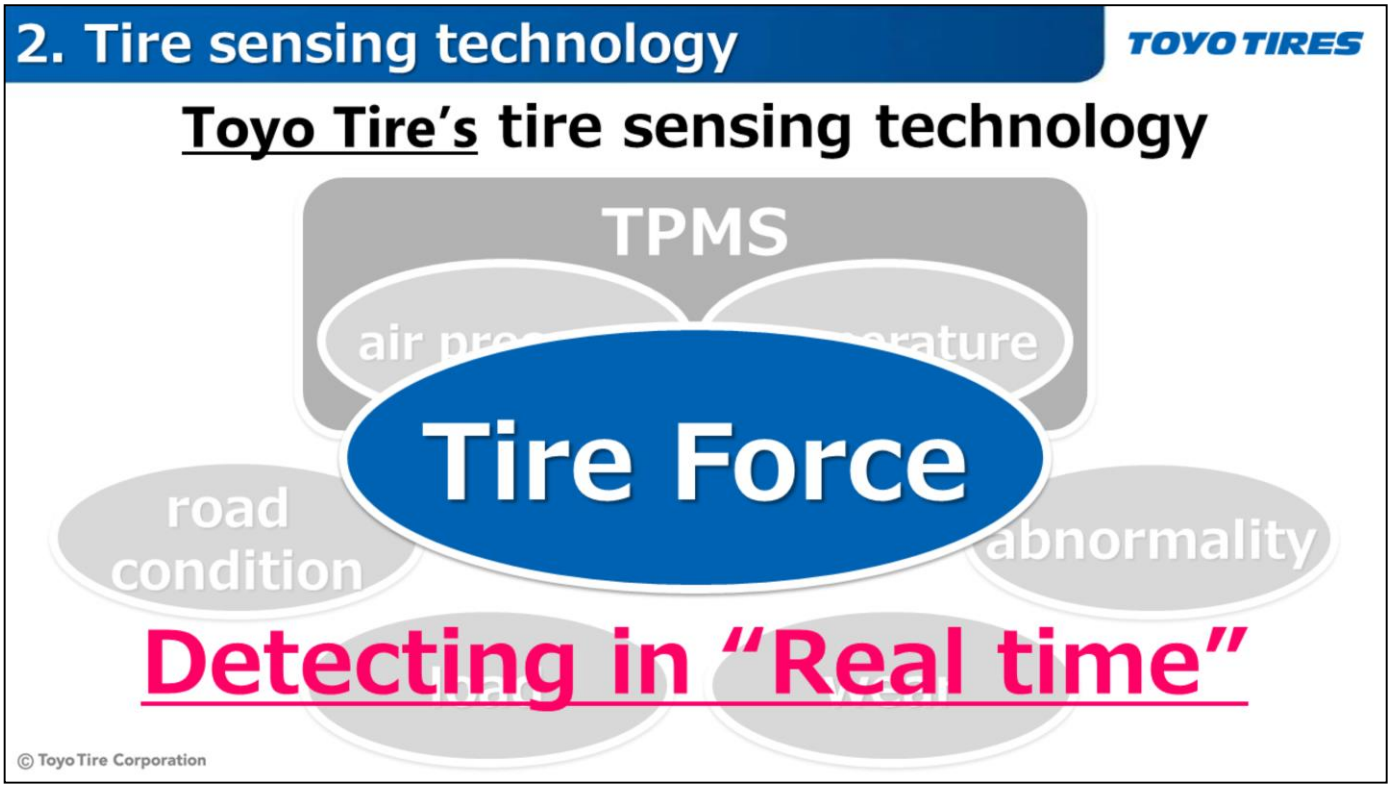
This is the approach adopted in tire sensing, that is, sensing of the tire and sensing with the tire.



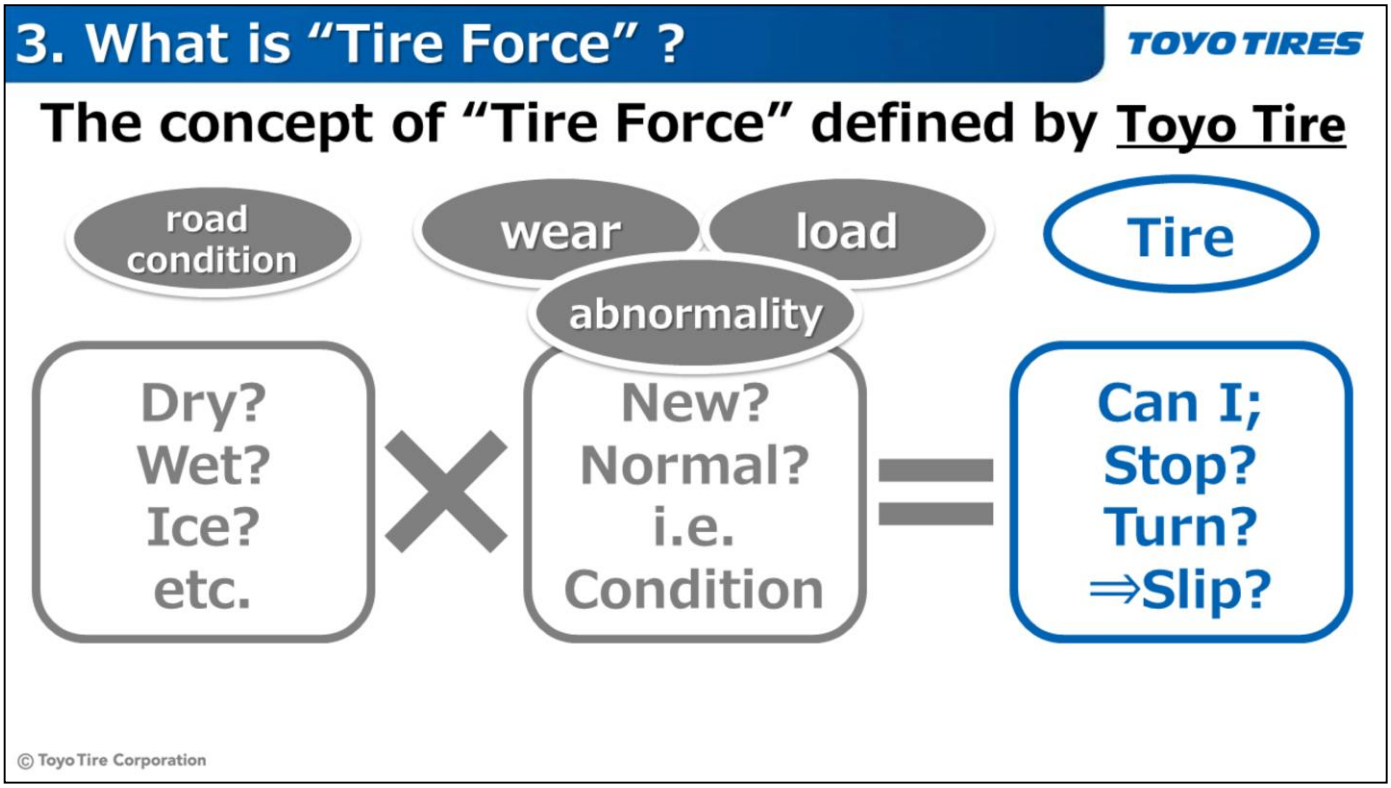
Research into tire sensing is taking place not only at our company but also at other tire manufacturers and related businesses.

An example of technology that has already been established is the tire pressure monitoring system (TPMS), which monitors tire air pressure and temperature.

Other technologies that have been disclosed are technologies that can detect road conditions (such as being wet, frozen, etc.), load on the tire, wear status and abnormalities.



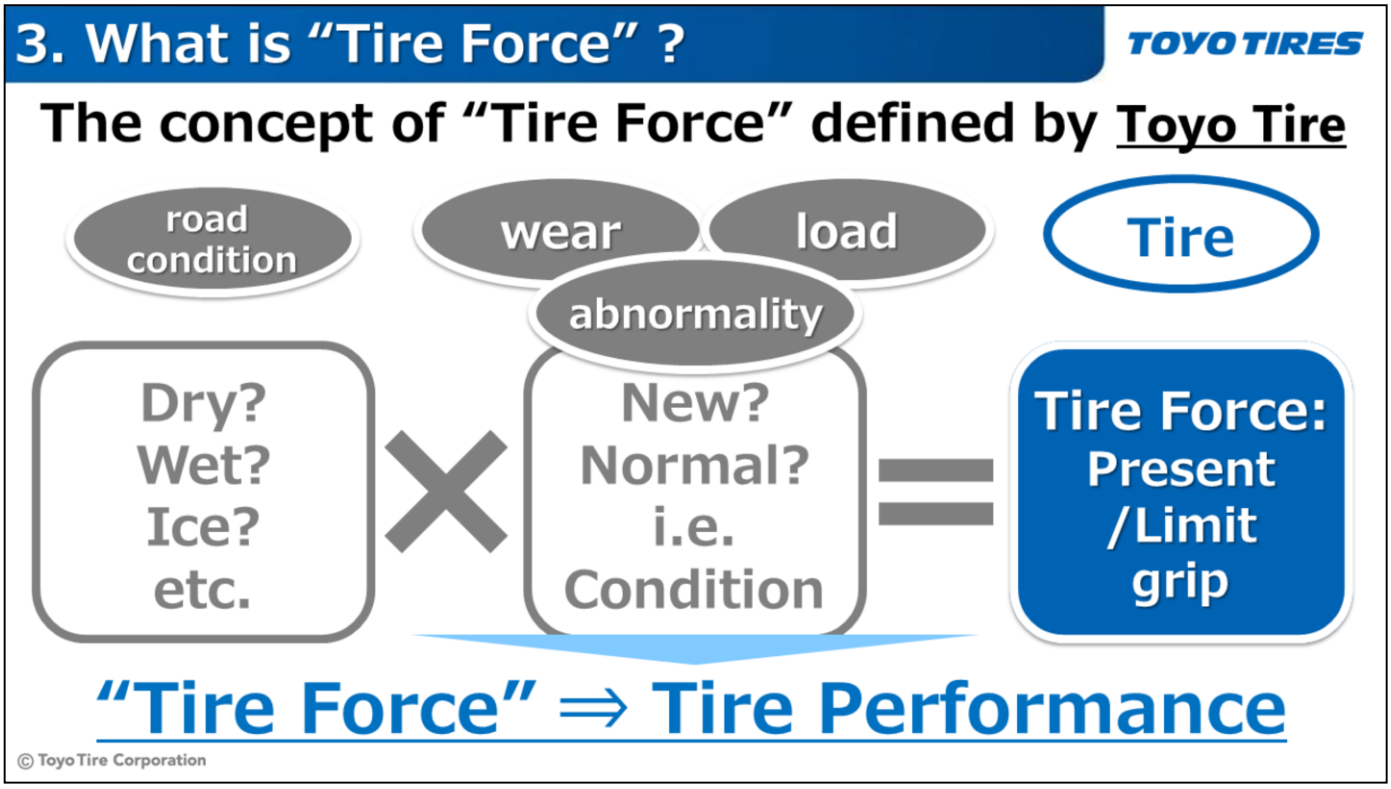
Against our competition, Toyo Tire presents its technology for detecting "tire force."
Additionally, tire force is detected on a real-time basis for vehicle safety.
The term "tire force" has been coined to express a concept conceived by Toyo Tire.
Let us explain the concept.



If, for instance, information on road conditions (whether it is wet or frozen) while driving and the condition of the tire at the time (whether the tire is new, worn, has problems, driving speed, etc.) is sent to the vehicle and the driver, the information that the driver wants and what the vehicle control system wants is "the performance of the tire presently in use."

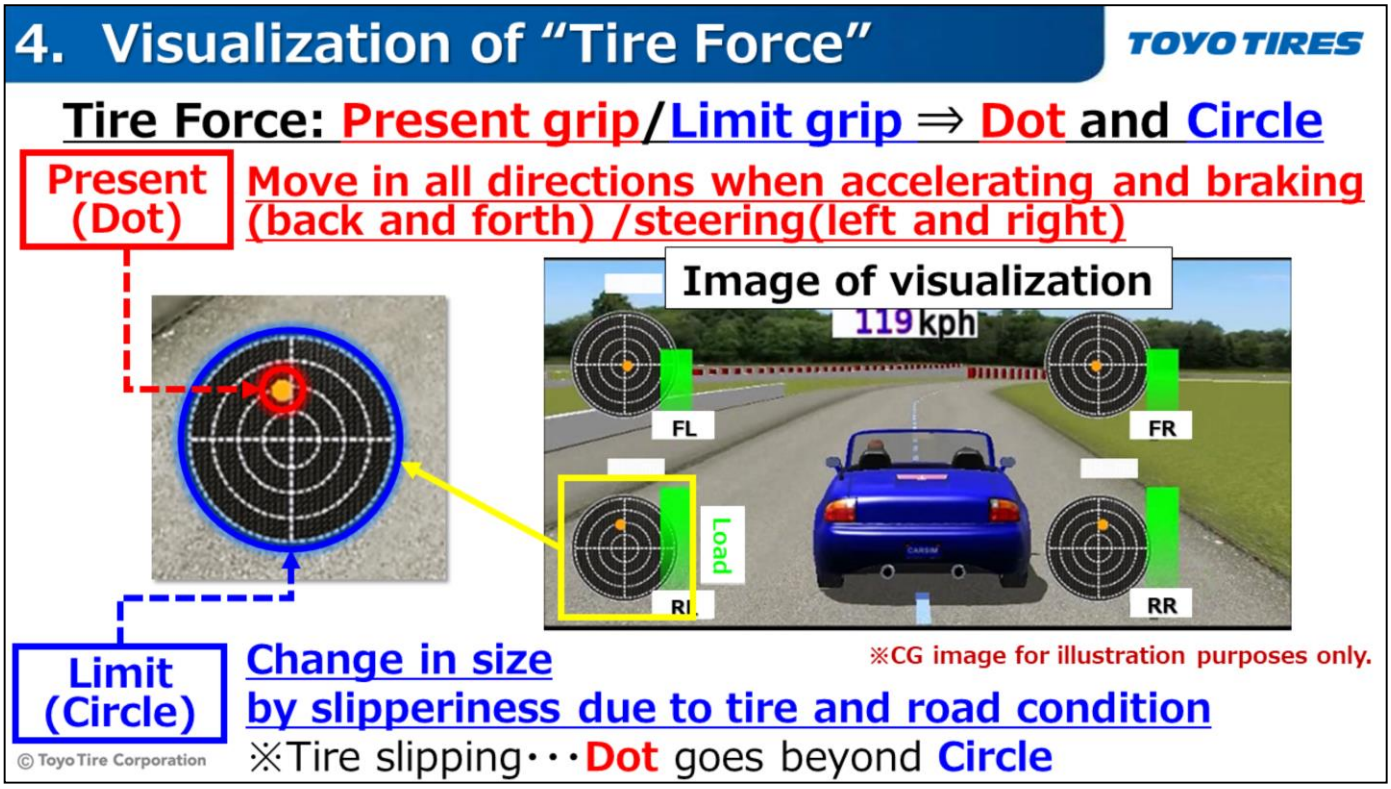
That is, whether the tire slips, whether it can corner or stop.

This is what Toyo Tire means by "tire force." In other words, it denotes the tire's "present grip force" and "limit in grip force."



Tire force points to the tire's performance while driving. It defines the tire's "potential" that can be identified after detecting the road conditions, wear status, load, abnormalities, etc.

It may be difficult to explain using words alone. Please look at the next page, showing a visualized image of tire force.



Toyo Tire's image of tire force is found in "the present condition and limit in grip force." As an example of visualizing strength, we use "dots" and "circles."

The present grip force is expressed in dots.

The limit in grip force is shown in circles.

The dots express the present grip force move left and right and forward and backward when accelerating, braking and steering.

The circles that denote the limit in grip force change in size, based on the slipperiness between the road surface and the tire that is affected by road conditions and vehicle speed.

If the dot (present condition) moves near the center of the circle (limit), you can see that the tire possesses grip force.

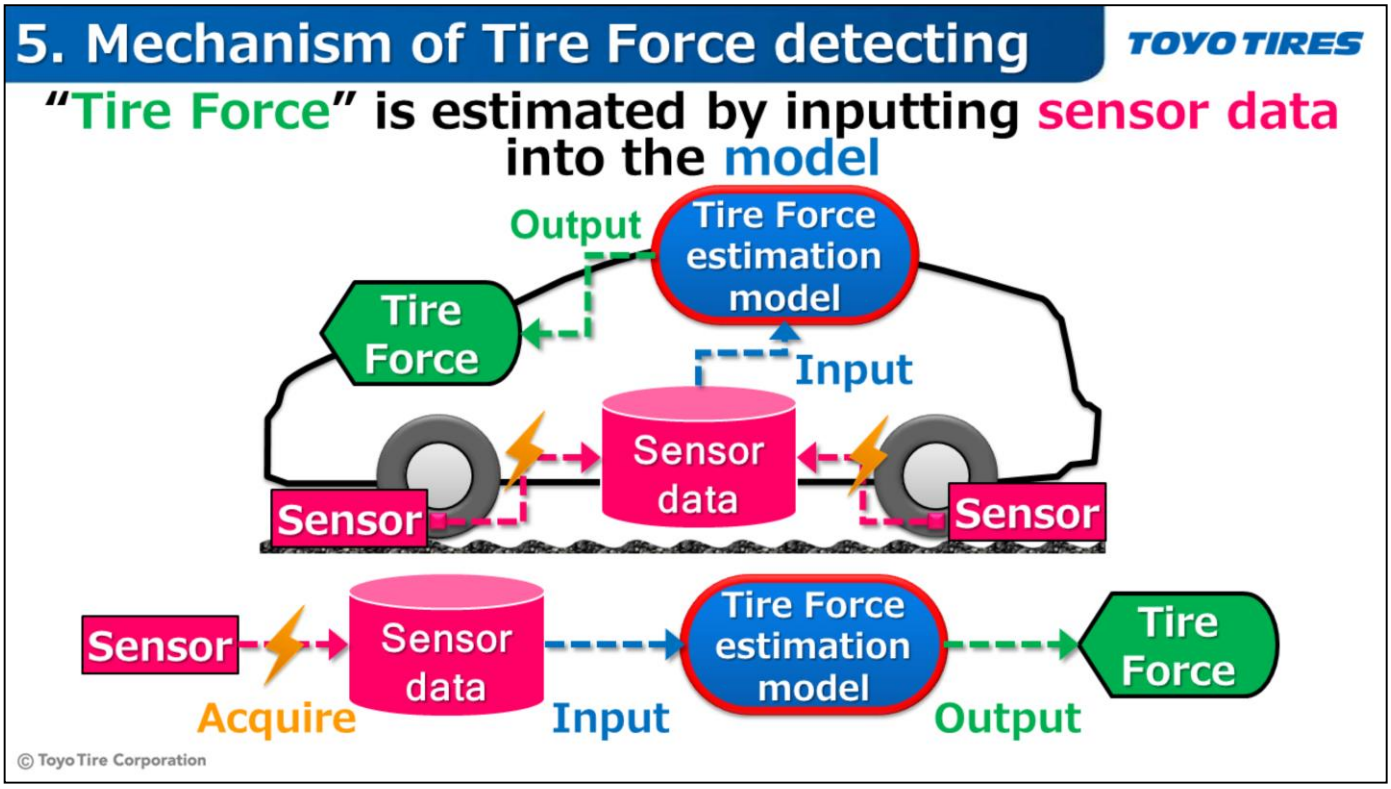
If the circle (limit) shrinks in size and the dot (present condition) moves closer to the circle (limit) circumference, you can tell that the grip force is reaching its limits. In other words, you can tell that the tire has become vulnerable to slipping.

From the dot (present condition) and the circle (limit), we can visualize the tire allowance (potential).

This is an image that expresses tire force utilizing dots and circles.

This is a simulated computer graphics image. The dots and the circles at the four corners provide a visual rendition of the tire force of each of the four tires.

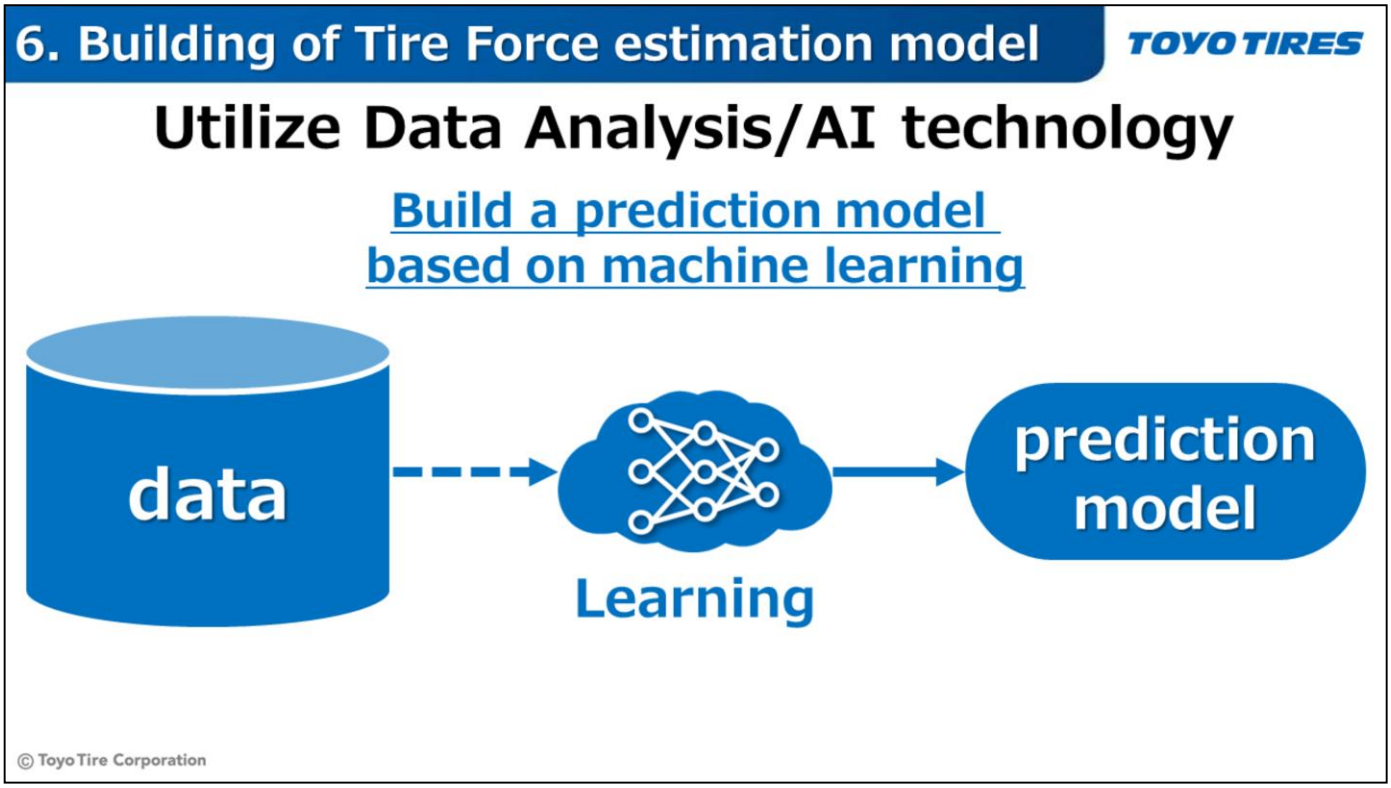
We have attempted to reproduce this CG output image in a real vehicle.



Sensors installed on the tires are used to detect tire force. The force is estimated by analysis and processing of acquired sensor data.

The scheme for producing tire force data output through the input of sensor data is the "tire force estimation model." This model is the core of this technology.

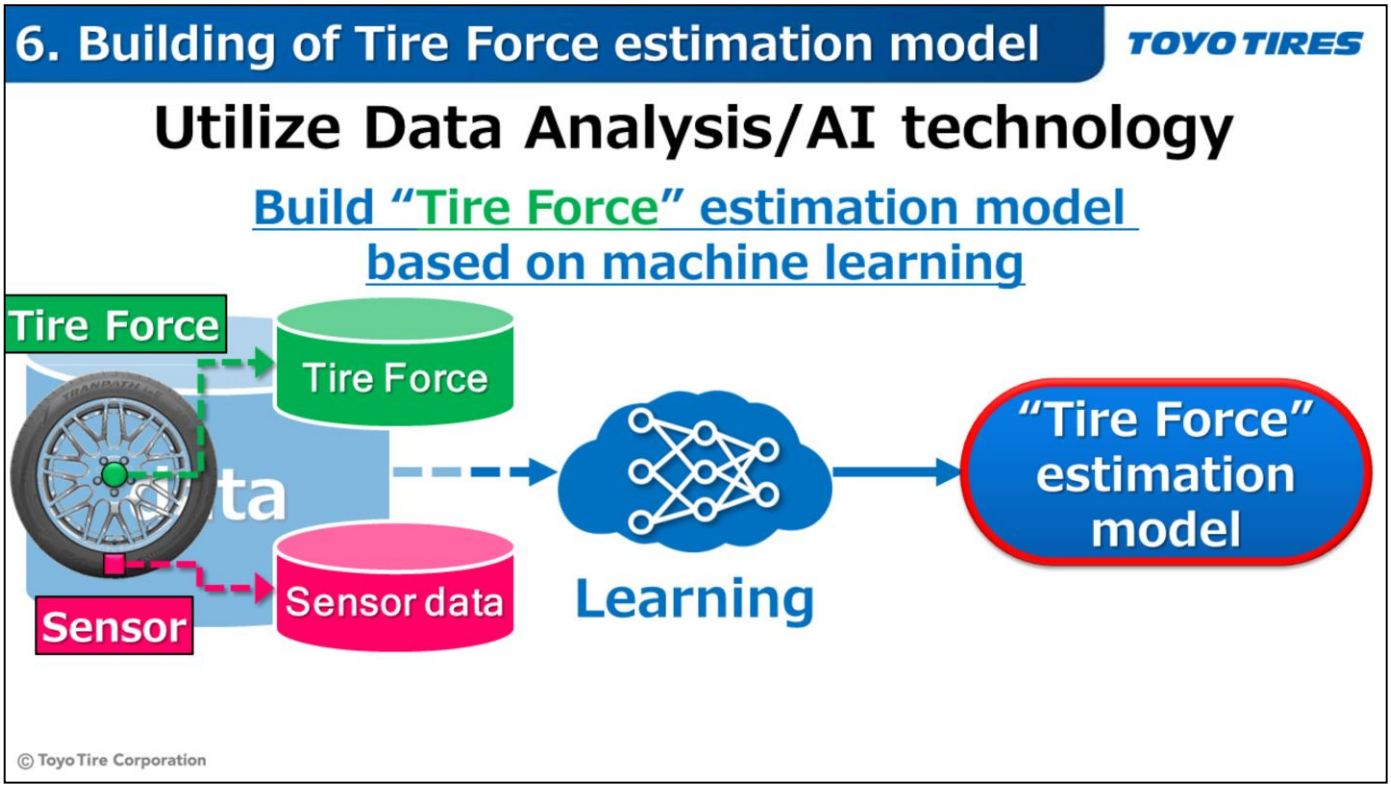
The tire force estimation model has been developed by utilizing data analysis/AI technologies that as of today have been applied in various business fields.



This page shows the flow of building the "prediction model" utilizing data analysis and AI technology.

Take, for example, the system in which the input of human voice (words) into the smartphone, etc. results in response (output). This is based on the scheme (model) of recognizing/determining the audio we received to predict the required response.

It has been created by gathering human voice data and the corresponding response (meaning) data, which has been used in data analysis and AI learning, in order to make predictions.



The same method has been applied in the building of the tire force estimation model.

In other words, the model has been designed to gather sensor data from the tire linked to corresponding tire force and learn from the data (data analysis/AI) in order to estimate tire force.

Data was gathered by installing tires equipped with a "tire force measurement device" and "wireless module and sensor" and synchronizing measurement data while driving. The data thus obtained was used for learning and building the model.

At first glance, the measured waveforms do not appear to be related to each other. However, computer learning/analysis helps identify their correlation.

* (Supplemental note) Tire behavior is related to "change in shape" of the tire's contact surface. The study was conducted on the belief that "change in shape" is correlated to "acceleration speed."

The estimation model thus created was verified with POC (proof of concept). After confirming the potential of the estimation model, data gathering began in full-scale in FY2019. Development was conducted through trial and error in the use of training data under a variety of driving conditions and learning methods.

7. Current state of development

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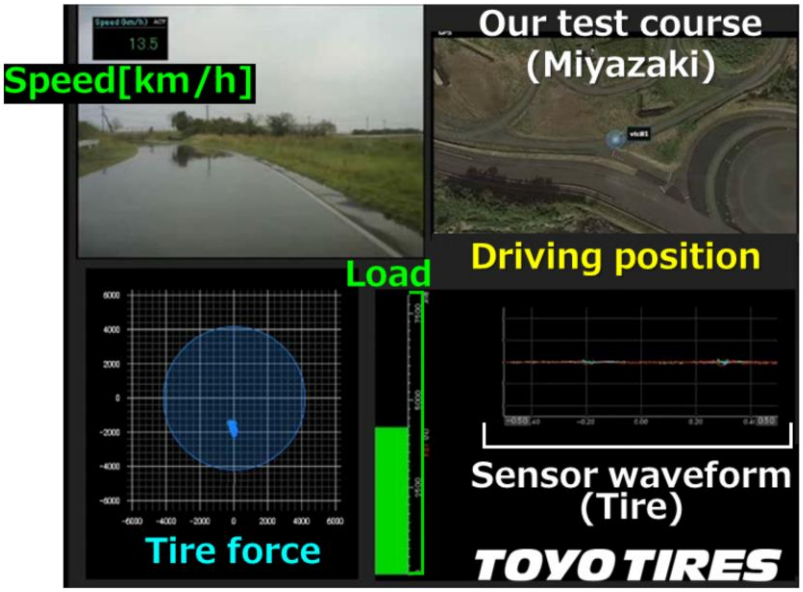
A reproduction of the concept



This page shows the current state of development.

The CG simulation output that you saw on page 6 has been reproduced with an actual vehicle on our Miyazaki Tire Proving Ground.

At the top left is the video of the vehicle cruising. It was raining at that time.

The top right shows the cruising position plotted on a map.

At the bottom right are the waveforms based on data from sensors installed on the tires. The waveforms are being analyzed and processed on a real-time basis.

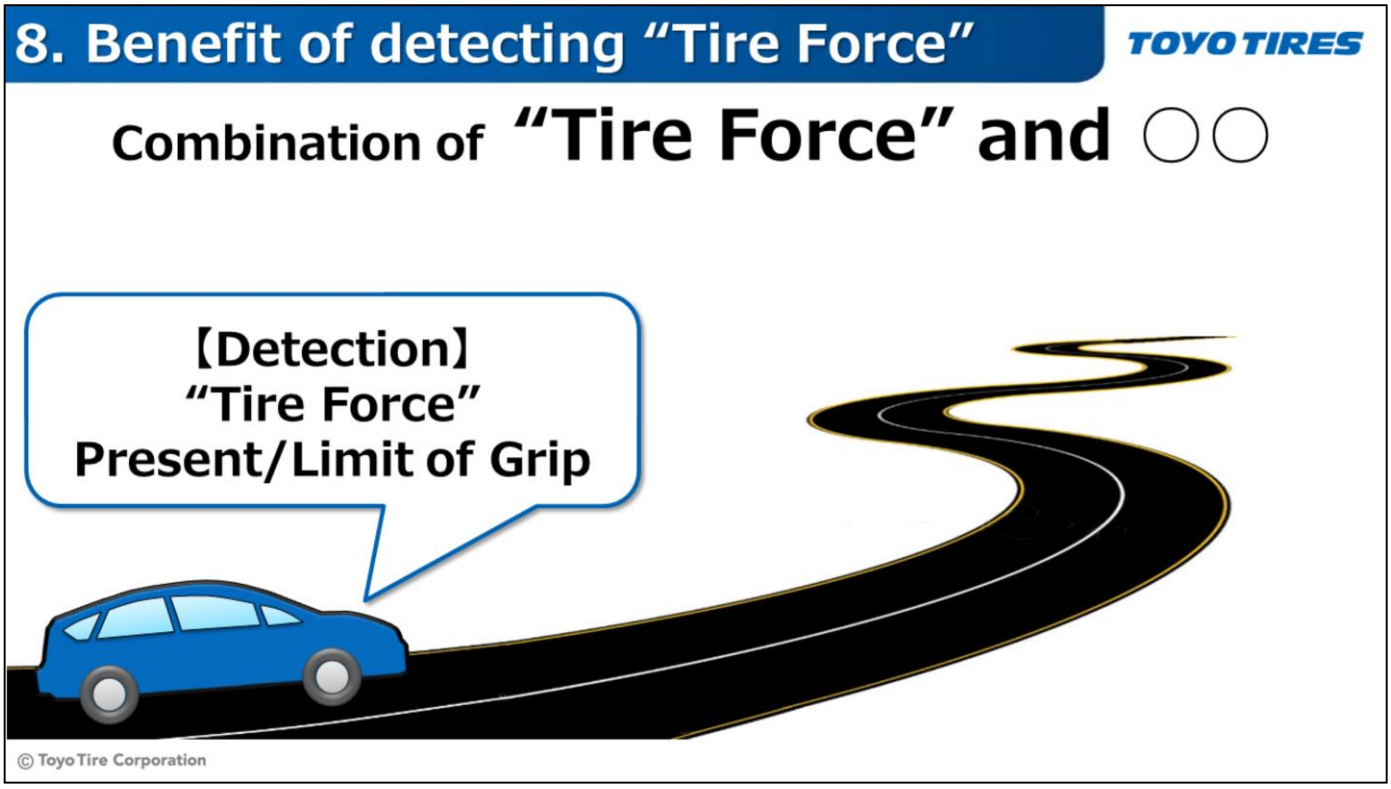
The results are shown at the bottom left as dots and circles, indicating tire force (present and limit grip force). The graph shows the load.

At present, we are able to reproduce the CG simulation output in real life to this extent at our tire proving ground.

In the future, we plan to gather data more widely, even on public roads.

Personally, I believe that this technology is exciting (thrilling) because it shows how the tires are performing right now, on a real-time basis.

Next, I would like to speak about what excitement (benefit) will be generated with the implementation of this technology.



I have already said that tire force detected with this technology can be interpreted as "how the tire is used" and "the potential of the tire" by showing it in visual form. I believe that the benefit (added value) can be increased further through the combination of tire force with other technologies and data.

8. Benefit of detecting “Tire Force” ①

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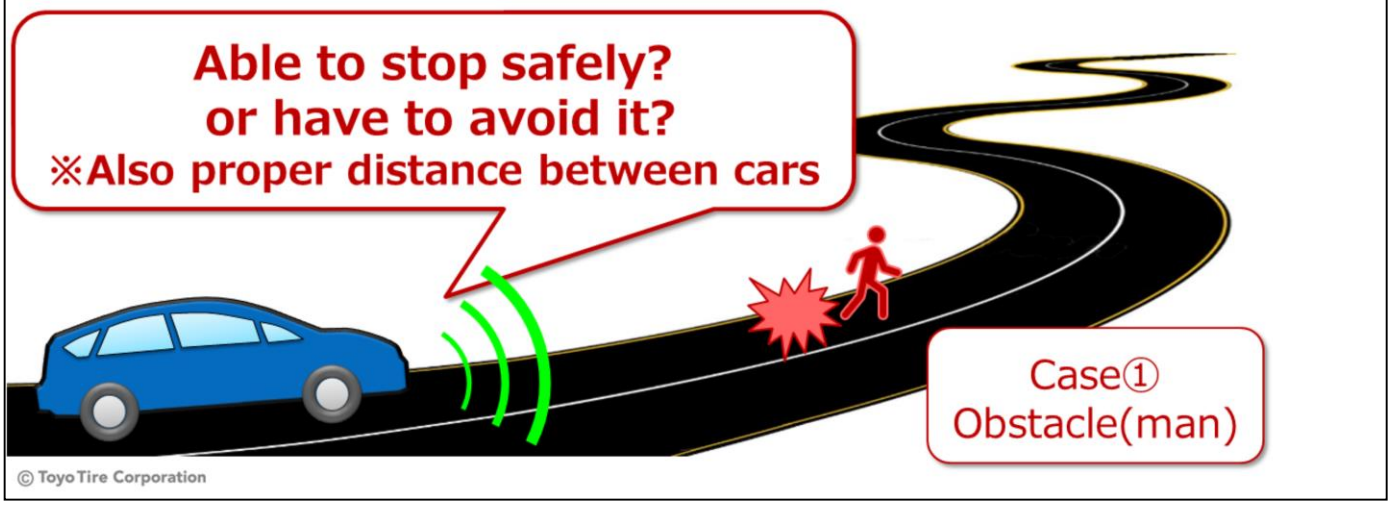
Benefit: Tire Force × Automatic braking =Braking distance



Let me show you the combination with automatic braking.

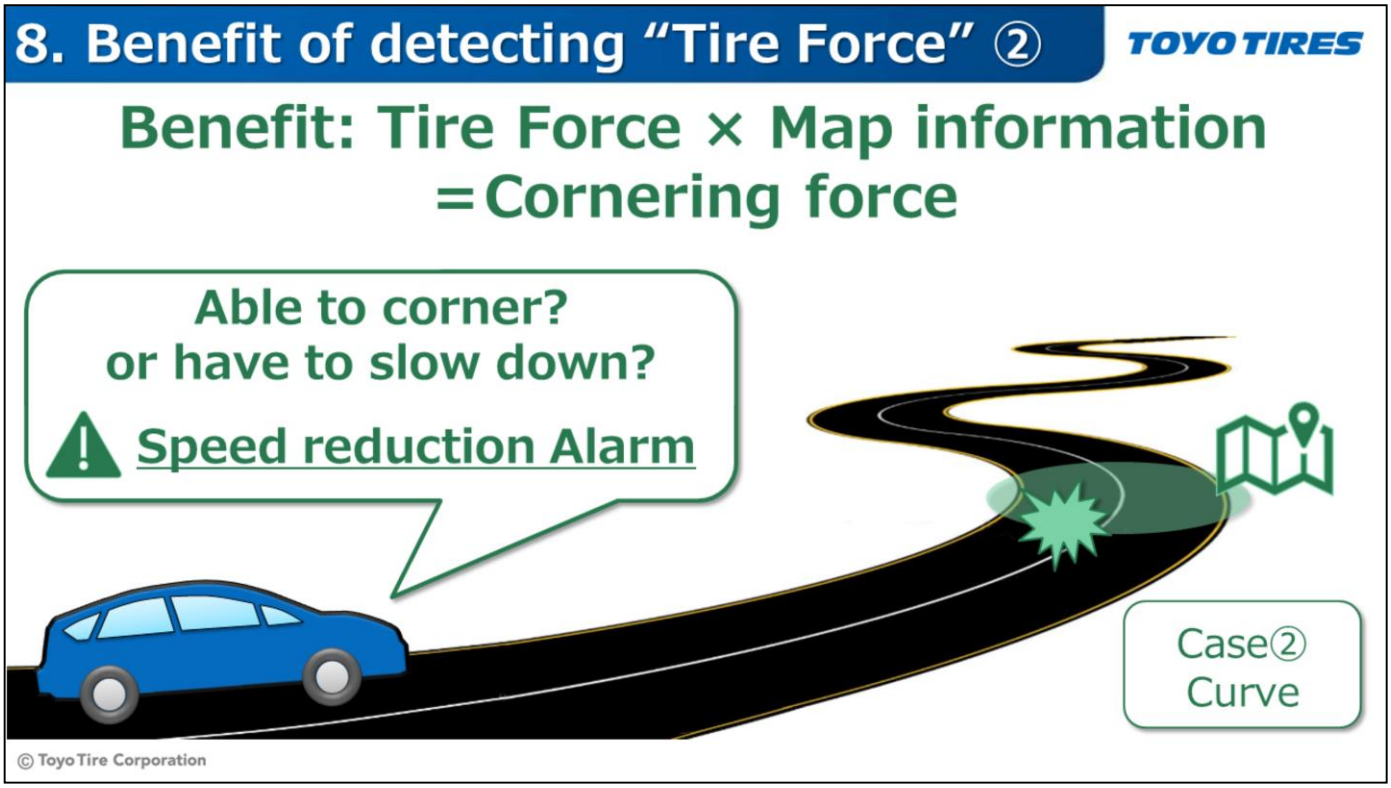
The combination of tire force with automatic braking will show the braking distance. This is added value.

* Braking distance: Distance taken from braking to actual stop.

In other words, the distance needed for an emergency brake to stop the car can be constantly computed while driving.

If an obstacle (person) is detected and automatic braking is set off, the vehicle can decide whether the vehicle is able to stop before hitting the detected obstacle or not.

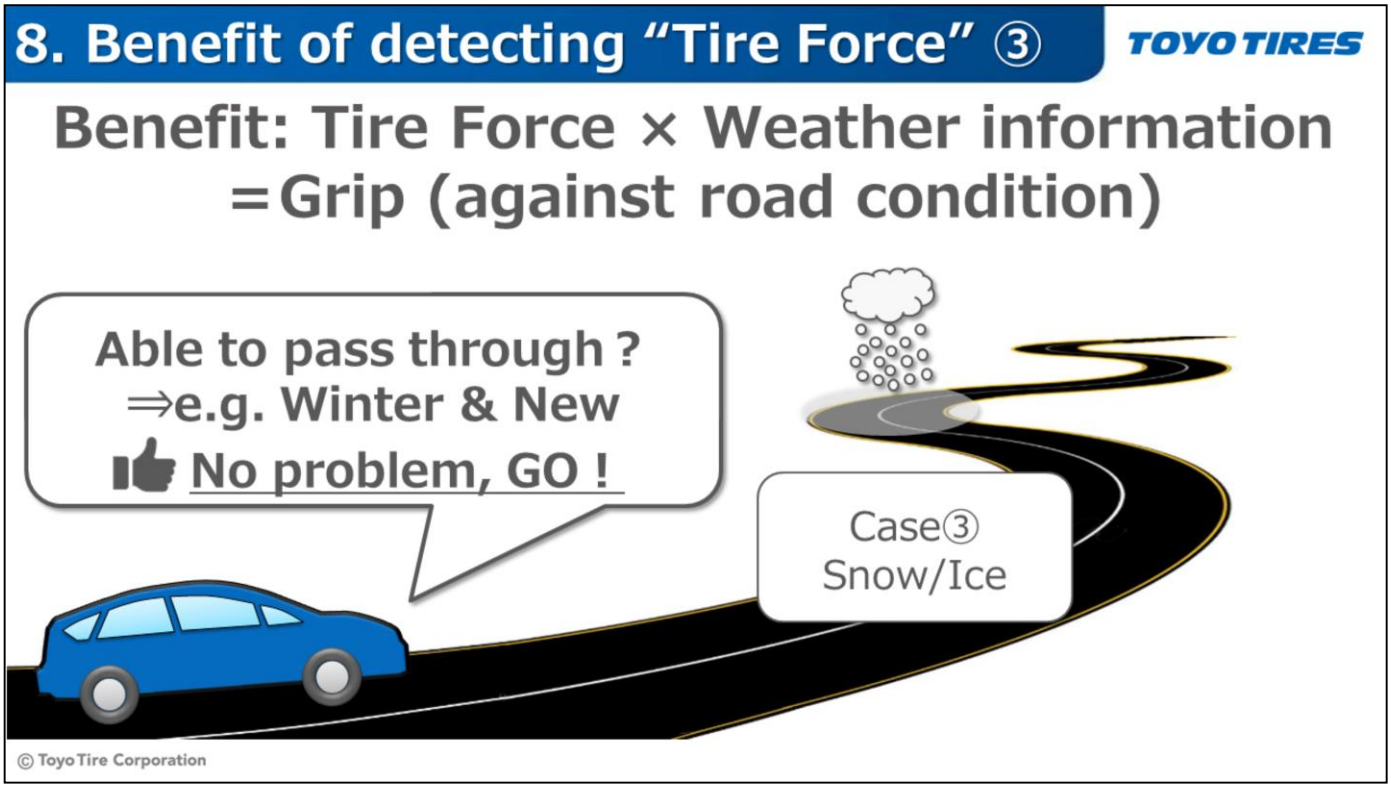
If it is not possible, there is a possibility for the vehicle to divert to avoid the obstacle or execute similar action. It may also be applied to maintaining an appropriate inter-vehicle distance on expressways or in autonomous platooning.



I would like to show you next the combination—with map information (car navigation data).

The combination of tire force with map information will show the grip force (cornering force) necessary when taking a curve. This is added value.

For example, if map information (car navigation data) shows that there is a curve ahead, it is possible to determine whether the vehicle is able to corner with the current tire conditions and speed. If cornering is not possible, an alert can be set off to control the vehicle, such as reducing its speed. I believe we will be able to support greater safety and security in mobility and public transit.



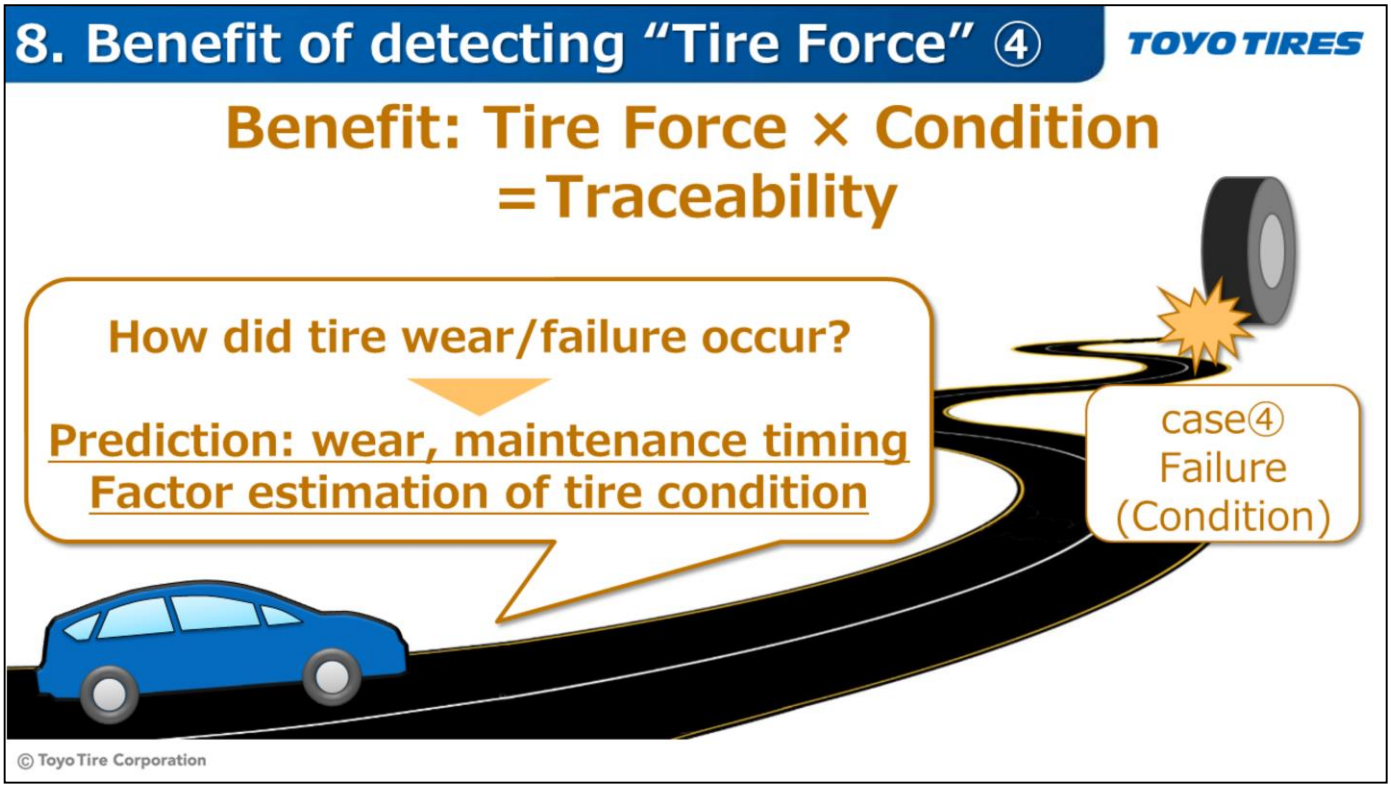
The next is combination with weather information.

The combination of tire force and weather information will help determine grip force over the road to be traveled.

Let us suppose that weather information provides data on the conditions of roads the vehicle is likely to travel.

If the weather information shows snowfall, the road surface is likely to be covered with snow or ice. A decision can be made on whether the vehicle can pass through it with the current tires.

If new winter tires were just installed recently and are certain to have sufficient grip even on snow cover or a frozen surface, the system may be able to report that "there is no problem traveling at the current speed."

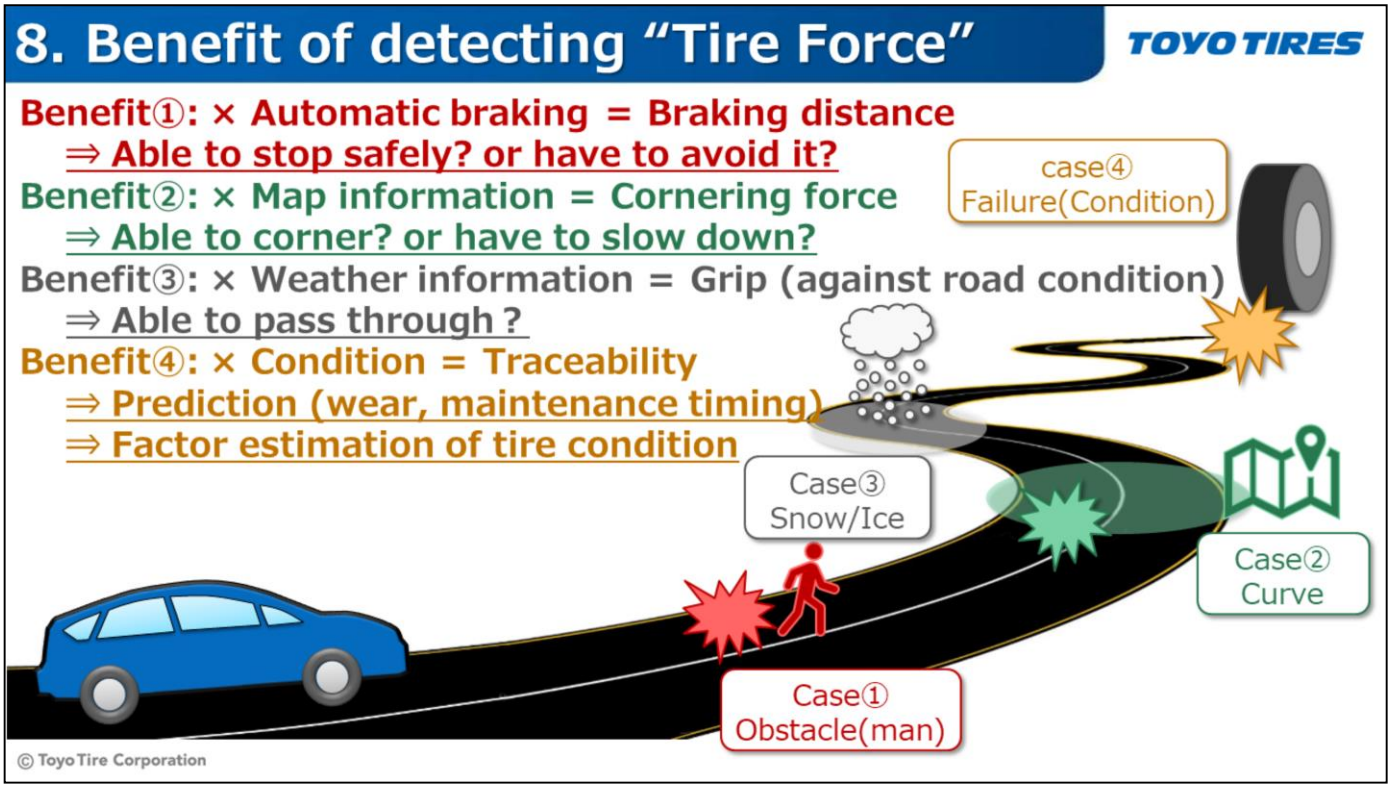


The fourth benefit is brought by combination with tire condition.

In other words, the tire's usage history and usage conditions to date can be tracked. In other words, the tire is traceable.

When a problem was found with a tire, it was common in the past to check the condition of the tire. With the system, it may be possible to estimate the cause of the failure, such as what developments led to the failure or what kind of use led to tire wear.

By utilizing tire history (previous process) for current tire condition (result) as data, we believe we will be able to predict tire wear or problems, develop a maintenance plan, propose tires suited to how they are used by the user, and the development of tires adapted to the tire use environment, among others.



Through the combination of tire force detected by our technology with other technologies, we believe that we will be able to deliver benefits across a wide range of aspects.

In addition to the four examples presented today, we are sure that there is great potential yet to be uncovered. We hope that the presentation of Toyo Tire's concept of tire sensing will lead to the creation of greater added value to be proposed for the next-generation mobility-based society and to co-creators of open innovation.


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Image of "Tire Force" visualization

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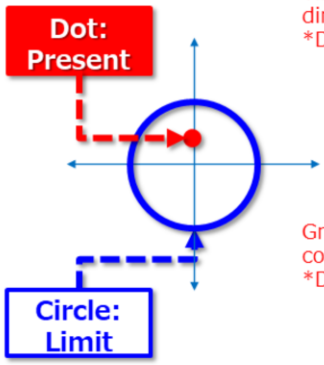
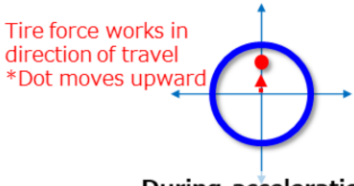
"Tire Force": Present/Limit of grip ⇒ Dot and Circle

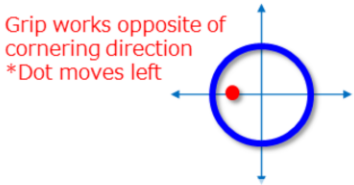
Present (Dot) ⇒ current grip force of tire
Limit (Circle) ⇒ allowance grip force of tire (potential)・・・Tire slipping: Dot goes beyond Circle



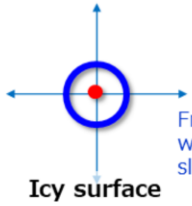
Visualization of tire force



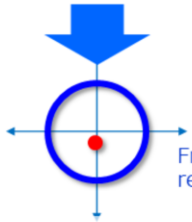
During acceleration



During right cornering



Icy surface



Deceleration or winter tires