

# DRIVING BEARING EVALUATION SYSTEM TO ACHIEVE ECO FIRST HAULAGE WORK

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**ABSTRACT:** This paper presents the drive bearing evaluation system to quantitatively describe and evaluate driving peculiarities and styles regarding dump truck drivers in a haulage work. The drive bearing represents appearance and motion in driving. It would provide site-manager and resident engineers with quantitatively suitable indices to guide or instruct drivers under their control with the objective of increasing haulage efficiency and achieving the ECO first haulage work. Firstly, this paper presents existing problems latent in a fleet management for a haulage work and the purpose of this study. Secondly, the ECO first haulage work is explained. Thirdly, described is the configuration of the drive bearing evaluation system that has a site process database in which actual driving data are preserved, and that automatically edits the data to produce daily and monthly reports and to issue driving evaluation cards for each driver. Fourthly, reported is the application of this system to haulage work of no-slump concrete for multilayer sediment control dam by unmanned construction in the Unzen restoration project. Finally, remarks are presented.

**Keywords:** *Driving Bearing, Eco First Haulage Work, Drive Bearing Evaluation Cards*

## 1. PROBLEMS AND PURPOSE

Although we often face capacity- and time-dependent heuristic indices or qualitatively instructions coupled to construction efficiency and energy-saving in a haul work, we have heard few the quantitative indices and the concrete instructions about it.

This paper presents the drive bearing evaluation system to quantitatively describe and evaluate driving peculiarities and styles regarding dump truck drivers in a haulage work. The drive bearing represents appearance and motion in driving <sup>[1]</sup>. It would provide site-manager and resident engineers with quantitatively suitable indices to guide or instruct drivers under their control with the objective of increasing haulage efficiency and achieving ECO first haulage work.

## 2. ECO FIRST HAULAGE WORK

Having said that, the drive bearing represents appearance and motion in drivings, which might impact construction efficiency and energy-saving regarding a haulage work.

The good drive bearing in the ECO first haulage work is supposed to have the following characteristics:

- Standard deviation of velocity might be small,
- Maximal numeric value of acceleration might be small,
- Absolute value of minimal deceleration might be small,
- Standard deviation of acceleration and deceleration might be small,
- Acceleration and jerk might have a bell shaped distribution with more or less the same sized tails on each side, respectively,
- Number of changes in acceleration and deceleration might be less, and
- Average of the squared jerks along the travel from a loading spot to the destination might be small.

The characteristics above are explained and found by explanatory variables, which include departure and arrival times, time elapsed for work performed at each work cell, distance travelled, number of round trips, average payload of a dump truck, velocity (travel speed), accelerations, number of changes in acceleration, that is to say, mean

crossing rate, jerks, trip time (loaded, empty), round trip time, cycle time per day or hour, and driving footprint.

The number of changes in acceleration shows the number that acceleration values stride across the average value as shown in figure 1.

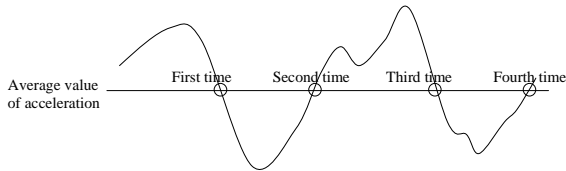


Fig. 1 Image of number of changes in acceleration

The uniformity of driving speed is represented by a mean crossing rate, which is derived from the following equation:

$$mcr = \sum_{i=1}^{n-1} \frac{|\text{sgn}(x_i - \bar{x}) - \text{sgn}(x_{i-1} - \bar{x})|}{2}, \quad (1)$$

where “mcr” is mean crossing rate, “ $x_i$ ” is the  $i$ th acceleration or deceleration for  $i = 1 \dots n$ , “ $n$ ” is the number of samples, “ $\bar{x}$ ” is the average value, and “sgn” is signum function.

The small value of the mean crossing rate represents few changes in the acceleration, that is to say, driving at the uniform speed. Conversely, the large one represents stepping on the accelerator and putting on the brake many times, alternately.

Consider the distribution of acceleration in figure 2.

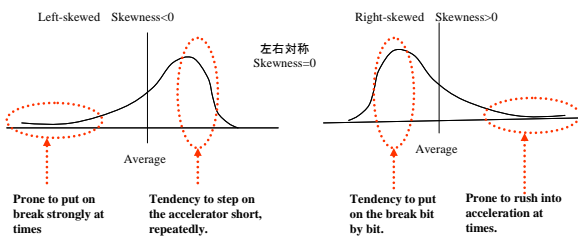


Fig. 2 Skewness of distribution shape of acceleration

The skewness is a measure of the lack of symmetry as to the distribution shape.

The skewness value is obtained by :

$$Skewness = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^3 / \hat{\sigma}^3, \quad (2)$$

where “ $x_i$ ” means  $i$ th observation for  $i = 1 \dots n$ , “ $n$ ” is number of samples, “ $\bar{x}$ ” is the average value, “ $\hat{\sigma}$ ” is standard deviation.

The skewness gives a visual method for appearance and motion in operations of accelerator and brake as follows:

- If the skewness value of acceleration should be negative, it can be conjectured that the driver is prone to put on the break strongly at times, and conversely, tends to step on the accelerator short, repeatedly;
- If the skewness value of acceleration should be in the neighborhood of zero, the driver might stably steer her/his dump truck under the better driving conditions; and
- If the skewness value of acceleration should be positive, the driver tends to put on the brake bit by bit, and conversely, is prone to rush into acceleration at times.

The average of the squared jerks is obtained by

$$ASJ = \frac{1}{n} \sum_{i=1}^n J_i^2, \quad (3)$$

where “ASJ” is average of the squared jerks, “ $J_i$ ” is the  $i$ th jerk for  $i = 1 \dots n$ , and “ $n$ ” is number of samples.

The small average of the squared jerks shows the high efficiency of the energy, conversely, the large one the low efficiency.

### 3. CONFIGURATION

The drive bearing evaluation system is a cloud software system, and can be rapidly provisioned and released with

minimal management effort, which is built in the collaboration, communication, construction and intelligent management (C3IM). The C3IM is a comprehensive, web-enabled system to enhance collaborative works and interactive communication, and to grasp significant information in order to support the unmanned construction, which aims to manage a fleet to ensure reliable construction operations at points on construction in such a hazardous environment [2].

The drive bearing evaluation system that has a site process database in which actual driving data are preserved, and that automatically edits the driving data to produce daily and monthly reports and to issue driving evaluation cards for each driver.

Staple functions of the drive bearing evaluation system are described below. Information flow when using the drive bearing evaluation system is shown in figure 3.

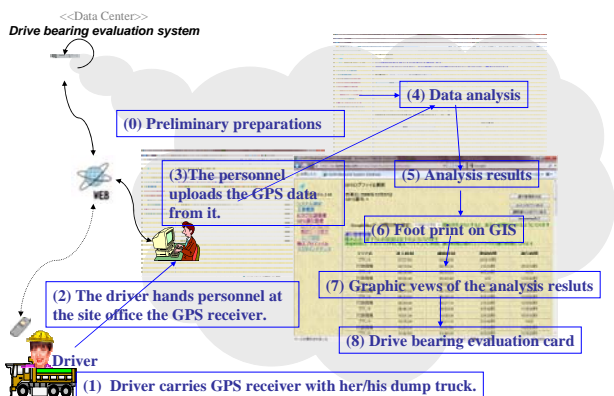


Fig 3 Information flow when using the drive bearing evaluation system

As the preliminary preparations, first of all, managed objects, such as drivers, dump truck, GPS receivers, users, types of materials, are registered in the drive bearing evaluation system. Subsequently, the haulage route from the borrow pit or the batching plant to the destination is divided into several distinct segments, considering the road conditions such as width, curvatures, grades, densely close proximity to residential area, etc. Figure 4 shows an example of a haulage route being zoned. Here,

regarding the distinct segments, the names, the coordinates such as longitude and latitude of the four corners, and the speed limits of driving are given. Users are able to confirm the coordinates displayed on the PC screen by putting the cursor on the point of the four corners.

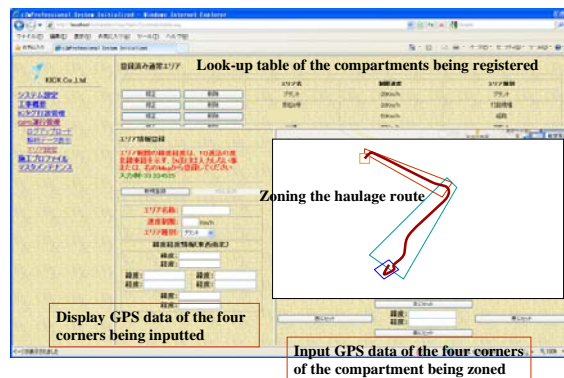


Fig. 4 Example of a display of the zoning

The each driver carries GPS receiver with her/his dump truck. After finishing her/his daily work, she/he hands personnel at the site office the GPS receiver. The personnel sends the GPS data to the drive bearing evaluation system built in the C3IM. Subsequently, the GPS data automatically are edited into numeric values of the explanatory variables regarding the drive bearing.

Those numeric values are calculated and summed up regarding the each distinct segment, and would produce information relevant to haul management. Examples of relevant information produced by the drive bearing evaluation system are shown below.

Figure 5 shows an example of the look-up table of the haulage operation one day.

Name of compartment	Ingress time	Egress time	Elapsed time within compartment	Trip time
<b>運行管理情報</b>				
積み込み、荷下ろしの状況は以下のようになります				
滞留時間は、そのエリア内に留まっていた時間、運行時間は前のエリアからの運行時間になります				
エリア名	進入時刻	離脱時刻	滞留時間	運行時間
積込場	19:06:26	19:07:28	1分2秒	
荷降場	19:11:15	19:13:02	1分47秒	4分49秒
積込場	19:16:05	19:17:44	1分39秒	4分50秒
荷降場	19:20:44	19:22:49	2分5秒	4分59秒
積込場	19:25:40	19:26:21	41秒	4分56秒
積み込み回数:3回 荷下ろし回数:2回 運搬量:11m3				

Fig. 5 Example of the look-up table of the haulage operation one day

Figure 6 shows an example of the graphic views of the transitions of the acceleration and the jerk in one week.

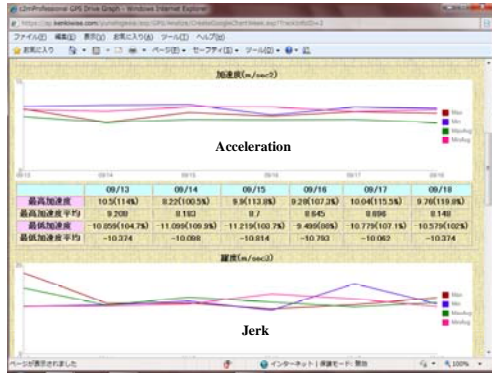


Fig. 6 Example of the graphic views of the transitions of the acceleration and the jerk in one week

Figure 7 shows an overview of the method of comprehensive evaluation of the drive bearing.

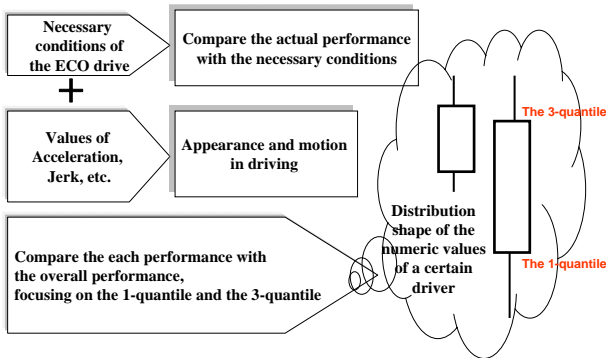


Fig. 7 Method of comprehensive evaluation of the drive bearing

According to the comprehensive evaluation of the drive bearing based on the above analysis results, the driving bearing evaluation cards would automatically be issued.

Looking at the information as mentioned above, it could make it possible to make suitable decisions on a timely basis and to promptly provide haul truck drivers with relevant instructions.

4. APPLICATION

Figure 8 gives an overview of the no-slump concrete haulage and placement in the Unzen restoration project [2]. The drive bearing evaluation system has been applied to no-slump concrete haulage by 10 tones dump trucks from the ready-mixed concrete batching plant to the spot where it is transferred to off-highway dump trucks as shown in picture 1. Subsequently, the off-highway dump trucks haul the no-slump concrete to the designated dumping spot.

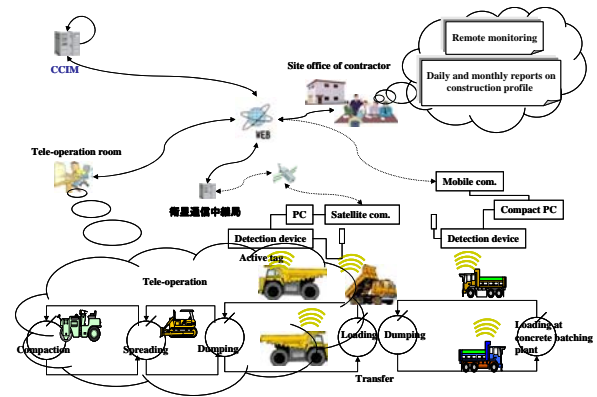


Fig. 8 Overview of no-slump concrete haulage and placement

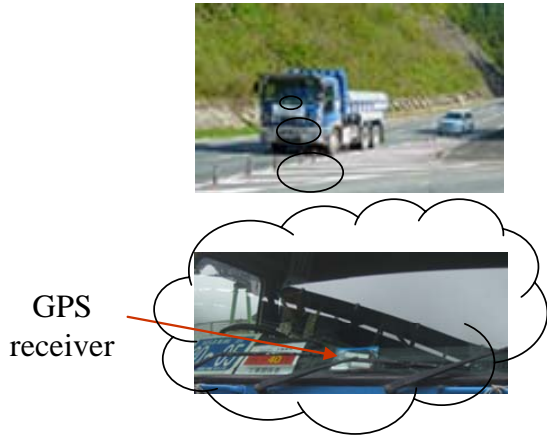
The driver put her/his GPS receiver included in a vinyl case is put on the dashboard of her/his dump truck as shown in picture 2.



Picture 1 Transfer spot

Figure 9 shows an example of the remote monitoring and control. The information on the display gives the current construction profile at one-minute intervals. Figure 10 shows an example of a driving bearing evaluation card issued as a comprehensive evaluation as to a driver. In addition, the information on the remote monitoring and

control can be confirmed by a cellular phone. The each driver could self-examine the appearance and motion in her/his driving and reflect on her/his own tendency to drive.



Picture 2 GPS receiver packed in a vinyl case is put on the dashboard

Figure 11 gives an example of the histograms regarding velocity, acceleration, jerk, etc. displayed on a cellular phone.

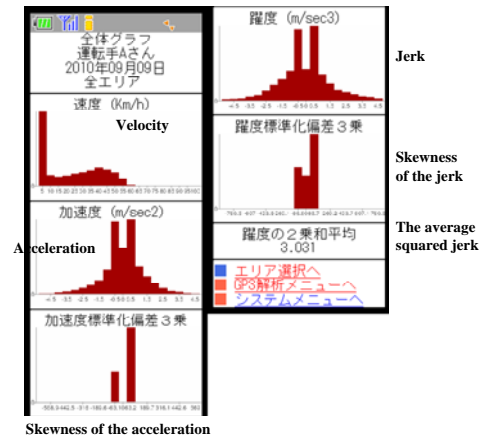


Fig. 11 Example of the histograms regarding velocity, acceleration, jerk, etc. displayed on a cellular phone.

Figure 12 shows an example of the graphic views of the transitions of the velocity, acceleration, etc. one week being displayed on a cellular phone.

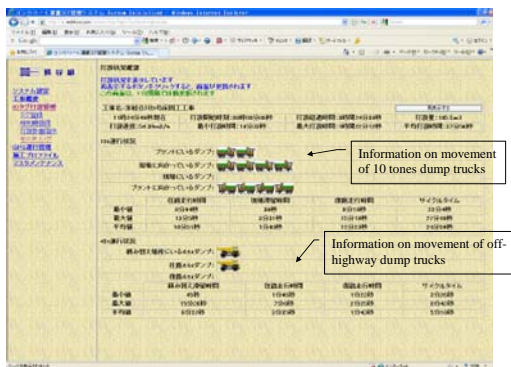


Fig. 9 Example of remote monitoring and control

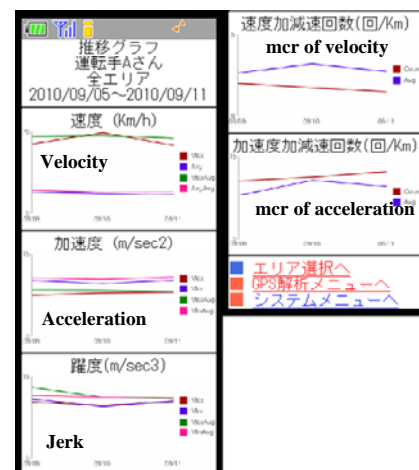


Fig. 12 Example of the graphic views of the transitions of the velocity, acceleration aetc. one week displayed on a cellular phone



Fig. 10 Example of a driving bearing evaluation card

An example of a driving bearing evaluation card as a comprehensive evaluation as to a driver is displayed on a cellular phone as shown in figure 13.



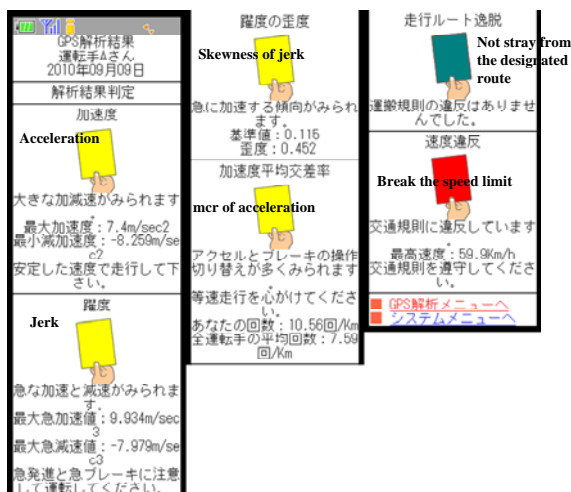


Fig. 13 Example of driving bearing evaluation card displayed on a cellular phone

**5. REMARKS**

On daily duty-cycle, the drive bearing evaluation system could provide site-manager and resident engineers at the Unzen restoration project with quantitatively suitable indices to guide or instruct drivers under their control with the objective of increasing haulage efficiency and achieving ECO first construction. In addition, the each driver could have opportunity to reflect on her/his drive bearing.

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