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TRAFFIC ACCIDENT ANALYSIS USING EDR DATA: A CASE STUDY OF A MULTICOLLISION EVENT

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Abstract. This paper focusses on the importance of using Event Data Recorder (EDR) data in the reconstruction of traffic accidents. It presents a case study of a highway accident in which aggressive overtaking led to a series of collisions between three vehicles. Although the speed recorded at certain moments was not accurate due to vehicle skidding, the EDR data allowed confirmation of key manoeuvres and movements of the vehicles prior to the collision. The paper highlights the importance of EDRs in accident analysis, where they helped reconstruct the drivers' manoeuvres and decisions, contributing to the elucidation of the causes of the accident. The mandatory introduction of EDRs in new vehicles from 2024 is an important step towards better crash analysis and improved road safety.

Keywords: EDR data, crash data, analysis of traffic accidents.

1. Introduction

An Event Data Recorder (EDR), often referred to as a vehicle black box, is a device that records key data on the operation of a vehicle at the time of an accident. These data include, for example, vehicle speed, brake system status, accelerator position, airbag activation, and seat belt status. EDR is an increasingly important tool for analysing the causes of road accidents and plays a key role in reconstructing the events that led to the accident [1–5].

EDRs were originally developed to improve vehicle safety and collect data for the automotive industry, but over time, their use has expanded into areas such as forensics and litigation. In the United States, for example, the National Highway Traffic Safety Administration (NHTSA) has established standards for EDRs and, since 2012, EDRs have been a mandatory part of new vehicles [1, 4–7]. In the European Union, this obligation is effective from 7 July 2024 [8].

This article focusses on a case study that shows a case where the recorded speed was not valid at a certain moment, but the data helped in reconstructing the accident itself and confirm the behaviour of the accident participants.

2. Traffic accident introduction

A traffic accident that occurred on a highway was used as a case study [9]. It occurred when a black vehicle aggressively overtakes a red vehicle from the right. As a result, the driver of the red vehicle attempted to avoid the collision and carried out an evasive manoeuvre. In the course of the manoeuvre, he drove onto the grass strip near the bollards that divide the road directionally. On reversing, the vehicle skidded, resulting in a first collision with the silver vehicle, which was currently travelling in the right-hand lane. The red vehicle continued to skid and struck the van standing in the breakdown lane. The EDR data played a very important role in the reconstruction of this accident and may have confirmed the facts and movements of the red vehicle. Figure 1 shows the accident process.

The data from the logger was read using Bosch equipment (Crash Data Revival 23.0.) and also by the Techstream system from the vehicle manufacturers Toyota, Lexus and Scion. The data read from both recorders correspond to each other and capture the same traffic accident.

3. CDR data

Five events were recorded throughout the accident (Figure 2). The first two incidents are associated with a collision between a red and a silver vehicle, and the remaining three are then associated with a collision between a red vehicle and a van. These can be determined from the recorded event lines. Events are identified in the CDR log by the abbreviation "TRG" (trigger) and the corresponding numerical designation. The event with the highest numerical designation is the last recorded event [9].

3.1. TRG 1

The first event was recorded as a frontal/rear/side collision, but the frontal impact was recorded as the triggering factor. The data are recorded in the time interval −4.7 to 0.0 seconds. This means that a pre-collision movement of the red vehicle of 4.7 seconds can be imported before the actual collision.

In Figure 3 you can see the speed of the vehicle. At a time of 4.7 seconds before the collision, the vehicle was travelling at $165\,\mathrm{km\,h^{-1}}$ and then accelerated to $171\,\mathrm{km\,h^{-1}}$ by 3.2 seconds before the collision, marked in red. During this time interval, the accelerator pedal

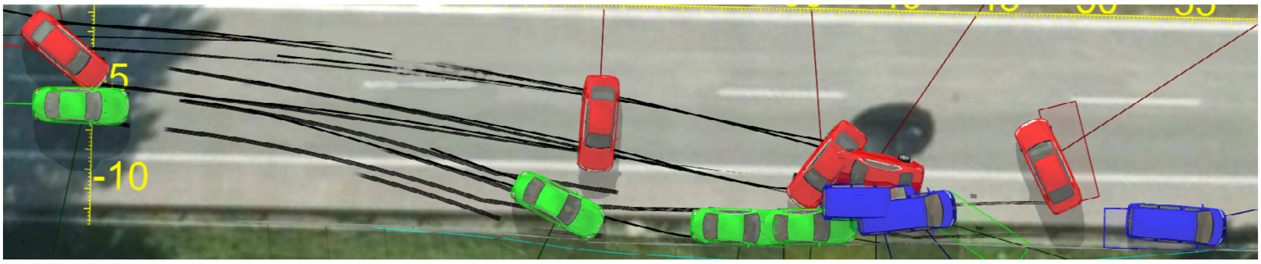


FIGURE 1. The accident process.

Event Record Summary at Retrieval

Events Recorded	TRG Count	Crash Type	Time (msec)	Pre-Crash Recording Status	Diagnostic Data Recording Status	Occupant Data Recording Status	Crash Info Recording Status	Time Series Recording Status
Most Recent Event	5	Side Crash	0	N/A	Complete	N/A	N/A	Complete
1st Prior Event	4	Frontal/Rear/Side Crash	-172.5	Complete	Complete	Complete	Complete	Complete
2nd Prior Event	3	Side Crash	-173.5	N/A	Complete	N/A	N/A	Complete
3rd Prior Event	2	Side Crash	-1595.5	N/A	Complete	N/A	N/A	Complete
4th Prior Event	1	Frontal/Rear/Side Crash	-1653.5	Complete	Complete	Complete	Complete	Complete

FIGURE 2. Summary of recorded events in the CDR log.

Pre-Crash Data -5 to 0 Seconds (4th Prior Event, TRG 1) - Table 1 of 4

Time (sec)	Vehicle Speed (MPH [km/h])	Accelerator Pedal, % Full (%)	Percentage of Engine Throttle (%)	Fuel Injection Quantity (mm^3/st)	Engine RPM (RPM)	Motor RPM (RPM)	Service Brake, ON/OFF
-4.70	102.5 [165]	100.0	Invalid	Invalid	5,700	15,200	OFF
-4.20	103.8 [167]	100.0	Invalid	Invalid	5,600	15,400	OFF
-3.70	105.0 [169]	100.0	Invalid	Invalid	5,600	15,500	OFF
-3.20	106.3 [171]	100.0	Invalid	Invalid	5,600	15,700	OFF
-2.70	106.3 [171]	0.0	Invalid	Invalid	5,200	15,700	OFF
-2.20	101.9 [164]	14.5	Invalid	Invalid	4,000	15,200	ON
-1.70	93.8 [151]	6.0	Invalid	Invalid	2,800	14,300	ON
-1.20	79.5 [128]	0.0	Invalid	Invalid	1,600	12,300	ON
-0.70	73.9 [119]	0.0	Invalid	Invalid	1,200	11,000	ON
-0.20	67.1 [108]	0.0	Invalid	Invalid	1,000	10,000	ON
TRG(0)	60.9 [98]	0.0	Invalid	Invalid	1,000	9,400	ON

FIGURE 3. Table of precollision data 1 (TRG 1).

was fully depressed (column "Accelerator pedal"), indicated in green. Subsequently, the brake pedal was depressed, and the vehicle was braked from 2.2 seconds before the collision (column "Service Brake"), shown in blue.

The braking is related to the manoeuvre mentioned above, which the driver of the red vehicle had to perform in an attempt to avoid a collision with the black vehicle overtaking him from the right. This manoeuvre could also be read and confirmed from the recorded steering wheel rotation and vehicle rotation values, Figure 4, columns "Steering Input", marked in green, and "Yaw Rate", marked in blue.

Before the vehicle driver started to brake, the steering wheel was slightly turned to the right, which was consistent with the course of the road itself. At the moment of braking, the steering wheel was turned to the left and then sharply back to the right 1.7 seconds before the collision. This caused the vehicle to skid. The fact that the vehicle entered the grass strip during the manoeuvre also contributed to the skid. The driver then tried to compensate for the skid by turning the steering wheel to its maximum angle. The steering wheel rotation values correspond with the vehicle's rotation values, where the vehicle was first turned slightly to the right and then turned to the left. Then, from a time of 1.2 seconds, the vehicle was on a skid and turned significantly to the right corresponding to values greater than $30^\circ\,s^{-1}$. As a consequence, from the moment of braking the vehicle, the recorded speed of the vehicle in the previous Figure 3 cannot be considered valid, or rather the recorded speed corresponds to the speed of the wheels turning, but not to the speed of the vehicle as a whole.

Pre-Crash Data -5 to 0 Seconds (4th Prior Event, TRG 1) - Table 2 of 4

Time (sec)	ABS Control Status	BOS Control Status	Brake Oil Pressure (Mpa)	Longitudinal Acceleration , VSC Sensor (m/s^2)	Yaw Rate (deg/s)	Steering Input (degrees)	Shift Position
-4.70	OFF	OFF	0.00	0.861	-1.46	-3.0	D
-4.20	OFF	OFF	0.00	1.077	-1.46	-3.0	D
-3.70	OFF	OFF	0.00	0.790	-1.95	-3.0	D
-3.20	OFF	OFF	0.00	0.861	-1.95	-3.0	D
-2.70	OFF	OFF	0.00	-0.646	-0.98	0.0	D
-2.20	OFF	OFF	1.63	-7.537	8.30	27.0	D
-1.70	ON	OFF	1.54	-7.752	-7.81	-40.5	D
-1.20	ON	OFF	0.53	-3.733	-33.67	-13.5	D
-0.70	ON	OFF	0.62	-4.809	-31.72	70.5	D
-0.20	ON	OFF	1.39	-2.225	-37.58	267.0	D
TRG(0)	ON	OFF	2.06	-8.973	-35.62	309.0	D

FIGURE 4. Table of precollision data 2 (TRG 1).

3.2. TRG 2

The second event related to the impact with the silver vehicle was recorded as a side collision and occurred 58 ms after the previous event. This time would correspond to the damage locations on the left side of the silver vehicle, see Figure 5, where the red color indicates the likely location of the first recording, i.e., TRG 1, and the yellow color indicates the stronger impact, i.e., the likely location of recording TRG 2.

In terms of the nature of the overall damage to the left side, it is clear that the red vehicle was not moving directly against the side of the silver vehicle but was moving at a small angle relative to its longitudinal axis. The collision therefore took place with a significant slip, but only to the point of greatest deformation, i.e. the point of the second entry marked in yellow in the figure. The intensity of the first impact was $16\,\mathrm{km\,h^{-1}}$ (Delta V).

In the second event, only the lateral acceleration values were recorded using sensors located on the B-pillar, C-pillar, and floor of the vehicle. The graph of lateral acceleration recorded by the floor sensor is best illustrated at Figure 6. This is because it shows the overall pattern of acceleration changes over the recorded time. Positive values represent acceleration from left to right, negative values from right to left. Initially, a slight acceleration from right to left can be seen, which at time -20 ms switched to acceleration from left to right. When the vehicle hits the other, the sensor accelerates to the left, corresponding to the impact of the right front corner so intensity of the second impact was with lateral acceleration $-27.6\,\mathrm{m\,s^{-2}}$. Subsequently, this impact caused the red vehicle to turn. This then corresponds to the next graph progression, i.e. the acceleration of the right rotation of the vehicle. This has gradually decreased as a result of the vehicle being in a sled.

Figure 7 shows the probable corresponding collision position of the vehicles that triggered the recording of the second event (TRG 2).

3.3. TRG 3 AND TRG 4

The third and fourth incidents were related to a red vehicle that crashed into a van in the breakdown lane.

FIGURE 5. Silver vehicle damage.

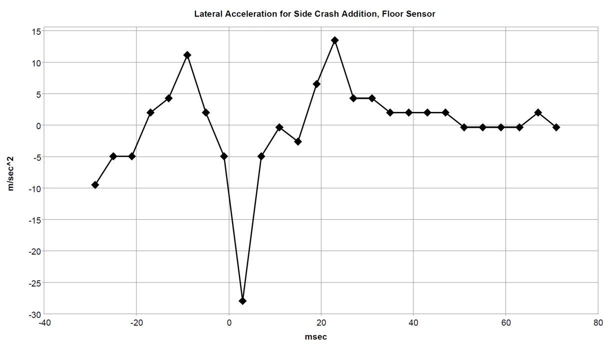


FIGURE 6. Graph of lateral acceleration of the vehicle (sensor on the vehicle floor).

The time difference between these events was one millisecond, so it can be said that it is one impact. 1.442 seconds elapsed between this impact and the previous impact.

The red vehicle was hit by the left side, specifically the part at the level of the left rearview mirror. It hit the left rear corner of the van, see Figure 8, which also corresponds to the damage on the left A-pillar of the red vehicle, which can be seen marked in green in Figure 8. Figure 9 shows the propable corresponding collision position of the vehicles that triggered recording of TRG 3 and TRG 4

The TRG 3 event was recorded as a side impact. As far as the data itself is concerned, only the lateral acceleration of the vehicle was recorded, similar to the previous event. All the already mentioned lateral acceleration sensors recorded a very strong lateral

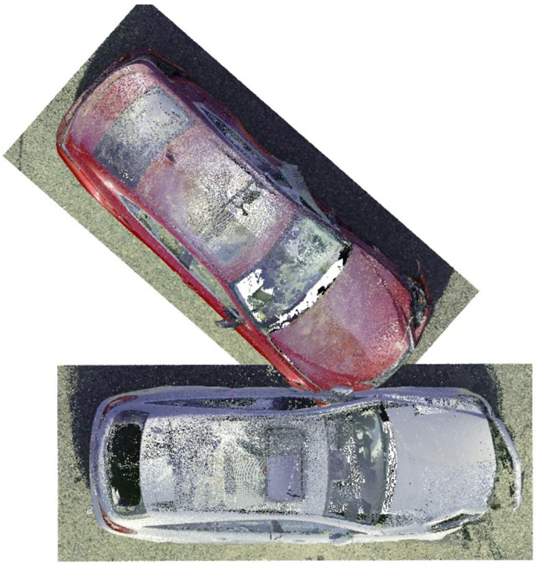


Figure 7. Vehicle collision position TRG 2.

(A). Damage to the left rear corner of the van.

(B). Damage to the red vehicle on the left rearview mirror.

Figure 8. Damage of vehicles (TRG 3 and TRG 4).

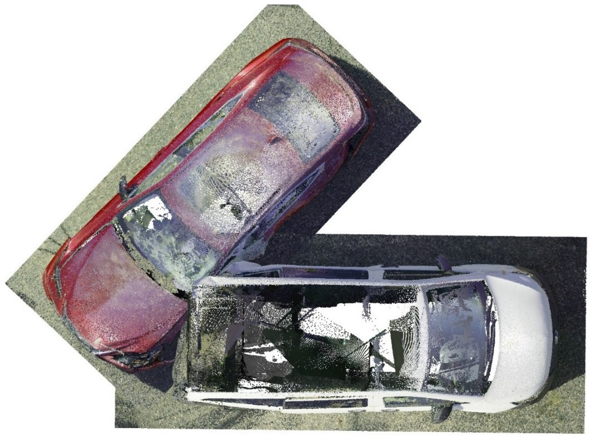


Figure 9. Vehicle collision position TRG 3 and TRG 4.

impact, i.e. acceleration from left to right. This acceleration reached peak values of almost $280\,\mathrm{m\,s^{-2}}$. The maximum value of lateral Delta V recorded in TRG 4 was $56.4\,\mathrm{km\,h^{-1}}$.

Event TRG 4 was recorded in its entirety, similar to event TRG 1. Data were recorded up to 4.6 seconds before the left side of the red vehicle struck the van. The fourth event is also related to the first recorded event in that an overlap of the recorded data can be observed. This means that the data recorded in event TRG 4 at 4.6 seconds before the impact is identical to the data recorded in event TRG 1 at 3.2 seconds before the impact with the silver vehicle in the right-hand lane, or before the first recorded impact. It is important to re-emphasise that the recorded speeds are not valid as the vehicle was in a skid. Furthermore, the impact speed of $20\,\mathrm{km\,h^{-1}}$, that is, the speed at time 0.0 s, is not valid as it does not correspond to the lateral acceleration of the vehicle that was recorded in the event TRG 3.

3.4. TRG 5

The last recorded event occurred 172.5 ms after the previous one and 1.6 seconds after the first one. It was recorded as a side impact that occurred as a result of the red vehicle rotating after striking the left side of the van. The corresponding vehicle damage that caused the recording can be seen in Figure 11.

In terms of the data itself, only the lateral acceleration values were recorded again. The values of all sensors showed an increasing and fluctuating lateral acceleration acting from left to right. Floor sensor for the lateral acceleration captured maximum value $36{,}8\,\mathrm{m\,s^{-2}}$. Therefore, these were secondary impacts of the red vehicle on the van due to vehicle rotation.

4. Summary

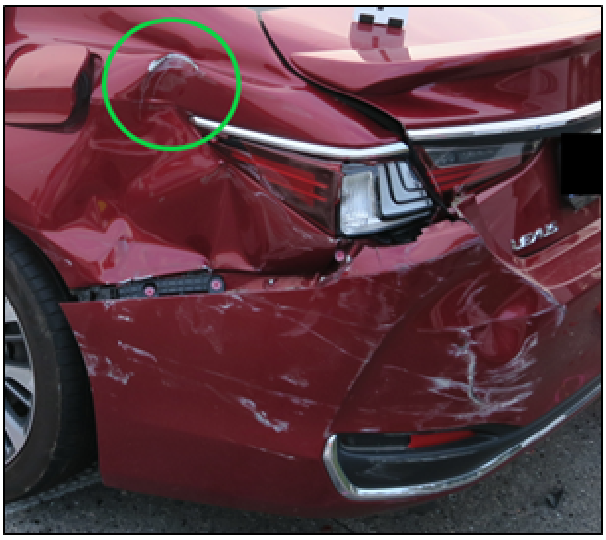
In the context of this accident, the accident data from the EDR recorder may have played an important role. The presence of the black vehicle was only mentioned in the statements of the accident participants. Since there was no CCTV footage available to confirm this

Pre-Crash Data -5 to 0 Seconds (1st Prior Event, TRG 4) - Table 1 of 4

Time (sec)	Vehicle Speed (MPH [km/h])	Accelerator Pedal, % Full (%)	Percentage of Engine Throttle (%)	Fuel Injection Quantity (mm^3/st)	Engine RPM (RPM)	Motor RPM (RPM)	Service Brake, ON/OFF
-4.60	106.3 [171]	100.0	Invalid	Invalid	5,600	15,700	OFF
-4.10	106.3 [171]	0.0	Invalid	Invalid	5,200	15,700	OFF
-3.60	101.9 [164]	14.5	Invalid	Invalid	4,000	15,200	ON
-3.10	93.8 [151]	6.0	Invalid	Invalid	2,800	14,300	ON
-2.60	79.5 [128]	0.0	Invalid	Invalid	1,600	12,300	ON
-2.10	73.9 [119]	0.0	Invalid	Invalid	1,200	11,000	ON
-1.60	67.1 [108]	0.0	Invalid	Invalid	1,000	10,000	ON
-1.10	46.6 [75]	0.0	Invalid	Invalid	900	6,800	ON
-0.60	30.4 [49]	0.0	Invalid	Invalid	900	4,800	ON
-0.10	14.9 [24]	0.0	Invalid	Invalid	800	2,500	ON
TRG(0)	12.4 [20]	0.0	Invalid	Invalid	800	2,200	ON

Figure 10. Table of precollision data 1 (TRG 4).

(a). Damage to the left side of the van.



(b). Damage to the left rear of the red vehicle.

Figure 11. Damage of vehicle (TRG 5).

fact, accident data was the only corroboration possibility. Data confirmed that the driver of the red vehicle had made an evasive manoeuvre consistent with avoiding a vehicle overtaking him from the right. Furthermore, the data confirmed the occurrence of a skid and therefore the rotation of the vehicle. All data could be considered valid, except for the speed of the vehicle. This was valid only up to the moment of skidding and subsequent vehicle rotation. Even so, the vehicle speed values before the collision, which could be considered valid, could have helped the expert as input data for the accident simulation. If the EDR had been implemented in the silver vehicle travelling in the right lane, it could have helped more with the analysis of the accident event and possibly with the generation of the accident event simulation.

5. Conclusions

Electronic Data Recorders (EDRs) are a key tool for detailed accident analysis, and their use is becoming an essential standard in the automotive industry. The study showed the important role that EDR data played in the investigation of a specific accident, where the recorded data could be used to accurately reconstruct the vehicle's movement and analyse the driver's reactions to the situation before the collision. For example, the data obtained confirmed an evasive manoeuvre that led the vehicle into the grass strip and subsequently skidded, which in turn led to a series of collisions.

The mandatory implementation of EDR in new vehicles opens new possibilities for even more accurate and comprehensive accident analysis. This technology not only facilitates investigations but can also serve as an important tool to improve road safety. In the future, the greater deployment of these recorders in combination with other advanced technologies such as autonomous driving systems or advanced driver assistance systems could significantly reduce the number of accidents and improve overall road safety. Therefore, EDR is becoming an invaluable source of data not only for forensic analysis, but also for research and development of traffic safety measures. However, it must be added that the validity of the data is not always 100 % and it is necessary to find the right methods to proceed with the data reading and the interpretation of the data itself, so that the data are not used without considering all the facts that occurred during the accident process and that may have influenced the data recording itself.

Acknowledgements

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