Paper 156

Proceedings of the Second International Conference on Railway Technology: Research, Development and Maintenance, J. Pombo, (Editor),
Civil-Comp Press, Stirlingshire, Scotland.

Managing Investigations in the Urgent Phase Following Railway Accidents

A. Bracciali[1] and M. Monti[2]
[1]Dipartimento di Ingegneria Industriale, Università di Firenze, Italy
**[2]Compartimento per Verona ed il Trentino Alto Adige
Polizia Ferroviaria, Italy**

Abstract

Railway accident investigations in Italy are carried out by several institutions, with different goals. Railway Police, a specialization of State Police, is the crime investigation department responsible for the surveys that must be done immediately after an accident. After defining the field of operation and the limitations of each of the subjects involved in the aftermath of a railway accident, this paper describes the experiences of the authors that were involved in a number of railway accidents that recently occurred in Italy. One of the weak points that were found in these cases was the limitation of Railway Police officers to take autonomous decisions without waiting for other subject's involvement, even in those cases where the root cause of the accident was absolutely evident. This limitation may be overcome by a specific teaching programme that allows Railway Police operators to fully understand the evidences that in some cases clearly emerge from the survey conducted after the accident. Such a programme, when properly structured (for example by using the European Standards in force for the normalization of rail components) and surveyed, could bring substantial benefits - saving both time and cost. While the first item is getting more and more critical for the modern railway infrastructure which is certainly more trafficked that in the past, the second could result from a noticeable simplification of investigations when there are no doubts on the causes of an accident. To such goal, the institution of a dedicated register of specialists is proposed to be set up, suitably trained with the procedures to be applied just after the accident.

Keywords: railway accidents, investigation, evidence, railway police, training.

1 Introduction

The pillars on which railways were founded are, in this order, safety, regularity of service (respect of the timetable) and minimum costs. Failures and accidents heavily impair functionality of the railway system which is still perceived to be a very safe (if not the safest) mode of transportation. Public opinion is deeply impressed by railway accidents as they involve people which are expected to travel absolutely comfortably and relaxed. Still more, accidents involving people living *outside* the railway domain are even less accepted by citizens and deserve a special attention as they are perceived as absolutely unacceptable.

The investigations that must be done after an accident tend to the identification of the causes and the responsibilities of the players involved in the railway environment, i.e., typically, the Infrastructure Manager (IM), one or more Railway Undertakings (RU) and the Entities in Charge for Maintenance (ECM).

While the inquiry is conducted by the Judicial Authority (JA) with the times and methods typical of such institution, the scene after an accident is normally inspected first by the criminal investigation department (CID) which, in the specific field, can be the Railway Police (RP). In the minutes and in the hours immediately after an accidents some critical decisions must be taken as two opposite requirements conflict: on one side there is the absolute need to preserve any evidence which could help to unveil the causes of the accident while on the other side there is the opposite need to restore as soon as possible the service in order to reduce at a minimum the disruption that inevitably follows an accident.

Several public institutions following different rules with different times and competences are involved in the investigations:

- The Ministry of Justice (MoJ);
- The Investigation Office of the Ministry of Transportation (IOMT);
- The National Safety Authority (NSA).

The goal of the IOMT is the improvement of the railway safety. In order to go in this direction the IOMT searches for the causes of the accident, focusing not only on direct causes but also searching for the indirect ones. The final reports of the survey contain safety recommendations proposed by the commission of inquiry or the investigator-in-charge.

From a legislative point of view the role of the IOMT is regulated in Italy by [1] which transposes the European Directive on Railway Safety [2], and each activity of the investigators is subordinate to that required for judicial purpose from the RP, to obtain information about a crime and preserve the evidences.

On the other hand the NSA has no legal obligations to conduct investigations on accidents but performs studies on events relevant for railway safety. The activity of the Italian NSA (Agenzia Nazionale per la Sicurezza delle Ferrovie – ANSF) is also regulated by [1] and is mainly oriented to the safety of the railway system with particular reference to the technical regulation of the sector.

According to the art. 55 of [3], the CID must perform all the necessary investigations to search for the authors of the crime and to avoid that crimes may results in further consequences. The purpose of the CID is thus to look for all subjects involved whose shortcomings played a role in the accident dynamics. Tt should not be forgotten that in Italy a railway disaster is a crime prosecuted according to art. 430 of [4].

The Italian legislation assigns the RP the task to operate in the rail sector. The RP, in accordance with the Public Prosecutor's Office, performs the measurements, collects all the available data and begins the investigation to find any responsible for the accident.

The IM, the RUs and the ECMs represent the third parties that, in this case, are involved in the casualty. As each subject has its own particular interest to defend, their investigations clearly tend to prove their extraneousness.

2 Typical phases after a railway accident

The aftermath of a railway accident is a complex and extremely dynamic situation that must be managed and coordinated at the best to avoid to make mistakes that could be detrimental for both human beings and, at a lower level of importance, and the preservation of evidences that could make light on the root cause of the accident.

As a first attempt, the following definitions could be given starting just after the end of the "mechanical phase" of the accident (i.e. when all the bodies involved in the accident have reached their final position):

1. **Phase 1 ("acute")**: the site must be made safe for injured people, for the survivors and for the operators (Fire Brigade, Rescue Teams, RP). Only emergency rescue operators can access the site. This phase is normally coordinated by the Fire Brigade as there may be residual risks of fire, contamination or fall of leaning objects. As a side effect, the destruction of some evidences is possible and this is accepted in the view of saving human lives;
2. **Phase 2 ("urgent")**: during this phase railway traffic is still interrupted, the accident area is still segregated, and only RP is allowed to go in. Inspection and survey are conducted "immediately after the accident", i.e. during the time lapse between the end of the acute phase and when the loss of evidences becomes possible. As examples, the following can be cited: temperature exchange (e.g. braked wheels/discs), material oxidation (due to rail or fog), dumping of tanks, etc. During this phase, RP is normally stressed by the request made by different subjects to reactivate the service as soon as possible In this step, the RP, responding to legal obligations arising out of the article 354 [3], informs the Public Prosecutor's Office and performs the objective survey according to a clearly defined and so-called "scientific" methodology. The measurements consist in the analysis of the crime scene to the look for any signs that can lead to the discovery of its causes. Pictures are taken of both the area of the accident and the details of potential interest. The RP questions persons involved and any witnesses. In order to preserve the evidences, RP seizes any stuff considered

relevant to the crime. The removal of any casualties must be authorized by the Public Prosecutor who pays a visit to the area in case of particularly serious accidents;

3. **Phase 3 (“completeness”)**: at the end of the preliminary activities of CID, in agreement with the Public prosecutor's office, the RP allows other entitled parties (IM, RU, NSA, IOMT) to access the area;
4. **Phase 4 (“cold”)**: after the end of CID preliminary activities, all the investigation bodies make their analysis on the basis of the collected documentation (not of interest in this paper).

3 Management of the “urgent” phase

Railway Police is a CID corp. that aims at keeping railway premises safe. It is normally distributed on the entire railway network of a country and it is operational 24h/7d along the year. This makes RP the natural entity to participate together with rescue corps to phases 1 and 2 being available on site in a very short time after an accident.

RP officers should be able to make a quick and correct analysis especially during the phase 2 (“urgent”) as follows:

1. “Rough” classification of the type of accident:
   - Natural disaster (landslide, whirlwind, flood, etc.): not of interest in this paper as out of control of RP following actions;
   - Technical factor, excluding events which are clearly due to immediately identifiable causes not linked to rolling stock or infrastructure (e.g. accident at level crossings due to vehicles occupying the tracks, fall of civil artefacts underlying, overlying or adjacent to the railway line);
   - Clearly identifiable human factors (e.g. suicides, terrorist outrages, etc.)
2. Decisions taken on the basis of evidences of exclusively technical nature, correctly applying the proper knowledge of the concept of “failure modes”:
   - If it is clear that the failure is a consequence of a long service and it is localized on the rolling stock (e.g. evident fatigue failures), do not make any further investigation on the infrastructure and authorize as soon as possible its restoration;
   - If rolling stock was evidently damaged only after the accident (bent parts, shocks with abrasion, etc.), make all the necessary investigations on the infrastructure such as (a) superstructure (track, ballast); (b) control / command issues (signals, point machines, etc.); (c) energy (electric substations / locomotive fires, etc.) and authorize as soon as possible the removal of the damaged rolling stock;
   - If neither the rolling stock nor the infrastructure show damages that fall in the two aforementioned cases it is necessary to perform further “cold” investigations including also human factors. In this case line re-opening may need to be delayed.

To correctly apply the principles of machine design and of mechanics of materials that are the basis of the evaluation that the RP investigator should perform during the "urgent" phase, it is worth to remind that safety related components of both rolling stock and track are normally designed for "infinite life", i.e. they should never fail during service if loads are correctly applied and maintenance is correctly performed. It is not rare to find heavily used vehicles with vital parts perfectly working after many decades (e.g. some axles last more than 60 years) and tracks are normally renovated for geometry defect reasons and not for expiration of the useful technical life of rails / fastenings / sleepers, etc..

Steels used in railway industry are normally ductile (i.e. exhibit good elongation during the tensile test and high fracture toughness) preventing brittle fractures. This is witnessed by the aspect of broken parts, which show a relevant portion (often over 50%) of bright and smooth surface where the crack propagated by fatigue while the remaining part of the section results to be irregular and rough where the fracture was sudden and brittle (e.g. axles, springs, wheels).

As long as fracture propagation under variable loads is a complex subject and depends on numerous factors, it is impossible that a structural component of a vehicle suddenly breaks for example due to an overload of a freight wagon. This makes useless to try to reconstruct the story of the "last trip": the fracture probably started months or even years before and it makes no sense to justify "the straw that broke the camel's back".

Another interesting and complex subject that lies outside the scope of this paper is the technical field dealing with non-destructive techniques (NDT) which aim at finding the health conditions of structural elements. As all measuring systems, NDT have a sensitivity limit (threshold) and should be complemented by statistical considerations about the Probability of Detection (PoD) and on fracture propagation laws in metals.

4 Some examples of clear origin accidents

4.1 Introduction

Normally every accident is due a set of causes that sum up in an unlucky way to produce an event that would have not happened if each cause were acting alone. For example, derailments are normally due to an uneven distribution of loads on the wheels but may be promoted by exceptional track defects (twist) that have normally no effect on non defective rolling stock.

Basically, the position of the IM and of the RU involved in an accident are apparently both valid and irreproachable:

- The IM may uphold that as long as hundreds trains pass on the track where the accident happened, the accident must have been caused by some defects in the rolling stock;

- The RU may uphold that as long as his rolling stock runs hundreds of miles every day, the accident must have been caused by some defects in the track.

Normally the investigation is quite complex and hardly the root cause can be readily found. Nevertheless, the rest of this chapter shows some cases where the root cause was found immediately and doubtlessly. It is trivial to conclude that a fast and correct identification of the evidences of the last kind can help speeding up service restoration.

4.2 Broken leaf spring

On 22 June 2009 a two-axle freight wagon (tank) carrying 26000 kg of a 85% solution of hydrofluoric acid derailed 30 km from Florence, Italy. The first author was named Principal Investigator of IOMT (but resigned before the end of the investigation for personal reasons).

The train stopped after having destroyed more than 4 km of track but luckily the tank did not break holding the very dangerous chemical product. After a short survey, the reason for the accident was discovered in the front left suspension of the tank, that showed evident signs of a fatigue failure of the main leaf near the eye mount. The fracture surface showed a smooth and bright surface where the fatigue crack progressed probably since long time, extending approximately for 40% of the total cross section of the leaf, while the remaining part of the surface was rough and irregular. As often in the case of fatigue failures, the sudden lack of useful section led to a brittle fracture, enhanced by the typical behaviour of steels for spring which have a relatively low (if not none) plastic elongation after tensile testing.

Figure 1 shows a picture of the derailed wagon (other vehicles were involved in the accident) and a close-up on the broken leaf spring. In this case the restoration of the railway line could have started immediately after the discovery of the fatigue-fractured element: no single element in the line can produce such a failures, as it results from a long story which is not related to the events that happened in the last moments of travel before the accident.

Figure 1: Railway tank derailed (left) after failure in the front left leaf spring (detailed right). Fatigue and sudden broken surfaces are clearly distinguishable.

It is important to highlight that the accident happened on the fundamental axis Milan-Rome and that the disruption to service were severe. In cases like this, saving one or two days can be beneficial to a nation's global passenger service.

4.3 Broken axle

On 29 June 2009 a two-bogies freight wagon (tank) carrying LPG derailed while passing through the station of Viareggio. In this case the tank opened after the contact with an external body (either a wing rail of a crossing or a post used for track alignment). Consequences were tragic, as LPG took fire and 32 people died as a consequence of it; many more people were injured and the survivors will carry the effects of this accident for all their life. Part of the town of Viareggio burned with extremely heavy costs for restoration. As long as the trial is still in progress at the date of writing, the following only aims at discussing the failure mode observed without any other consideration.

Newspapers reported the day after the accident some pictures taken on the scene were a broken axle was found split in two parts, one still belonging to the wheelset and the other remained in the axlebox (Figure 2). Deeper investigations after the accident confirmed that the root cause of the accident was the broken axle whose fracture surface exactly shows all the features of a shaft subjected to rotating bending under a moderate-to-low average load.

Also in this case the root cause of the accident appears clear. The attention of the investigators focused in fact on the tracks that the tank hit *after* the derailment and *not before*, meaning that there is a general consensus that the track *before* the point where the accident started has no relevance in the accident. The first author was involved in the past years in the trial dealing with ultrasonic inspections but he is not involved anymore in this accident.

Figure 2: Axle broken in Viareggio as reported by the newspapers (left) and pictured during investigations after the accident (right).

4.4 Displaced wheels

On 6 June 2012 a freight wagon passing through the Bressanone station on the Brenner line derailed without consequences on people. The wagon was the first after the locomotive, and the derailment involved the locomotive, the wagon itself and a number of following vehicles. Luckily wagons were carrying scrap steel for foundries located in the North of Italy, so no risks of fire or contamination were present in this case. The second author was involved as RP officer, while the first author was involved as the technical expert for the RU that supplied only the traction (freight wagons involved belonged to another company).

The first wheelset was found with both the wheels displaced from the seats while the fourth wheelset had only one of the wheels displaced (Figure 3). Quite surprisingly, the aspect of the wheelseat surfaces were found without any defects, meaning that probably the displacements of the wheels was not due to a sudden condition (such as an abnormal braking or an exceptional force encountered during the service) but resulted from an abnormal mounting condition that had no relation neither with the track nor to the actual service.

Figure 3: Displaced wheels from the wheelset on the first wheelset of the wagon (left). Aspect of the surface after wheel displacement revealed no defects or damages typical of wheels pressing off (right).

Also in this case the reason for the accident was the vehicle and the infrastructure had clearly no responsibilities in what happened. This was later confirmed by the investigations that showed how the tolerances that had to result in a firm press-fit of the wheel over the axle were not observed.

4.5 Derailment on a curve

The website [5] represents an authoritative and interesting source on the accidents that happened in the Swiss railway network. Although none of the authors was involved directly in the accident, the event happened in Chiasso on 23 March 2012 is a good example of an accident due to causes that lie in the track instead of on the rolling stock.

A locomotive derailed at low speed during shunting in a curve after a turnout. The rail is fastened to the sleepers via steel baseplates, coach-screws and K-fastening as shown in Figure 4 and in Figure 5. The investigators found that the wooden sleepers were old and deeply damaged; many coach-screws were missing resulting in an exceptionally laterally flexible rail that displaced under the action of the locomotive.

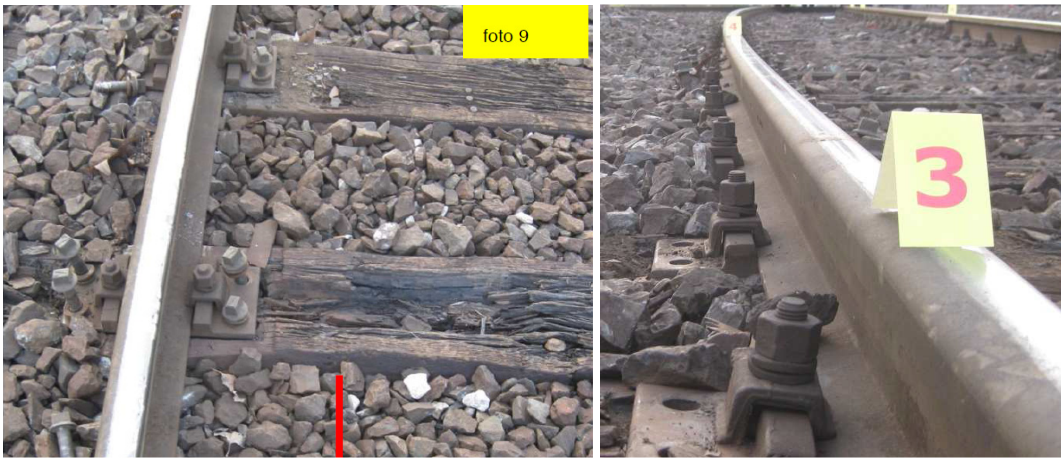

Figure 4: Aged conditions of wooden sleepers on the turnout in Chiasso responsible for the derailment of a locomotive.

Figure 5: Detail of the baseplate with missing coach screws.

After the running conditions of the locomotive (speed) were checked, the locomotive has been removed and the track restored. A following check of the running gear dimensions in the local workshop confirmed the investigator's intuition, i.e. the fact that the track was the responsible for the derailment and that the locomotive was just a victim of a poorly maintained infrastructure.

5 Improvement of technical skills of RP officers in Italy

5.1 Current situation

Railway Police in Italy is a specialized branch of State Police. From an operating point of view, the investigations on railway accidents are performed as follows:

1. A five-people squad specialized on railway accidents ("Nucleo Operativo Incidenti Ferroviari – NOIF") that intervenes only in case of major accidents [6];
2. Railway Police ("Polizia Ferroviaria – Polfer"), structured in 15 Departments ("Compartimenti") evenly distributed across the country, that intervene for "normal accidents";
3. Each Department has a brigade of CID that intervenes on the accident site making "urgent surveys" according to art. 354 of [3].

Railway Police personnel that first reach the site of an accident do not often have the aforementioned technical skills sufficient to perform the appropriate survey during the "urgent" phase (note: the lowest acceptable education level is junior high school without special requests on technical issues). Although an all-purpose course including a module on accident survey is already supplied to RP personnel, "training on job" often remains as the main opportunity to improve technical knowledge on railways.

As a result, at the moment even in the case the RP personnel working on an accident site finds the root cause of an accident, they can only report to Public Prosecutor and wait for his decisions to allow for infrastructure restoration operations to start.

5.2 Creation of "first intervention squads" (FIS)

The presence spread over the territory is a resource that should be exploited at its best. Although it is evident that special training cannot be supplied to all RP personnel, the definition/creation of "first intervention squads" (FIS) within each Department could solve the current limitation of a fast and precise interventions on the accident site. The definition of the number of RP inspectors that should form a FIS and the technical equipment that they should have available will be the object of a future work.

FIS personnel should be selected on the basis of some prerequisites, that, briefly, could be:

- Knowledge of railway technical issues;
- Knowledge of the English language and preferably of another language (French, German, Slovenian, Croatian) for border Departments;
- Previous experience in the field of railway accidents and investigations;
- Availability to follow specific training courses;
- Availability to work in emergency situations (short notice);
- Attitude to team work.

One of the commitments of the FIS spread on the territory would be the creation of a data base with the information collected during "urgent" phases and the exchange of information between all the FIS during an annual meeting. Note that this data base is not in contrast with data bases set up by other bodies (NSA, IOMT) as it would contain operational practices that normally do not belong to those files.

5.3 Training definition and methods

Many of the main lines of European Countries belong to the Trans-Eurepean Network of Transportation (TEN-T Railways) and are regulated by Technical Specifications for Interoperability (either High Speed or Conventional Rail), or TSIs for short.

It results that TSIs are by definition the best harmonised set of European Rules and that they naturally constitute the best candidate to be used as teaching aids during a technical training on railway safety.

The main modules should describe and analyse in detail the peculiarities of the main subsystems involved in case of a railway accident:

- *Rolling Stock*: wheelsets, braking system, bogie frames, carbody, buffers and draw gear, etc.;
- *Infrastructure*: rails, fastenings, sleeper, ballast, switches & crossings, rail joints, track geometry parameters;
- *Control/Command*: as a general information,

to supply their description, the working principles of the various parts and some basics of railway mechanics, technology of materials and NDT.

The training should be supplied by competent and authoritative boards, such as the Universities and the NSA, even if the contribution of experts from other institutions (RU, IM, retired technicians, etc.) is envisaged. In any case, at the end of the training a final exam is forecast with a given validity (to be defined), and the obligation to participate to the annual meeting where each operator shall report his experience.

6 Conclusions and further developments

Despite the importance given by the European institutions to railway safety, the considerable increase in the railway traffic, the increase in operating speeds and the liberalization will very likely result in the future in some railway accidents. As known, any complex system can fail even if all measures are properly followed at least for some unknown reasons or uncertainties. That's why investigations carried out after an accident will require in the future highly specialized and motivated investigators with competences that were not needed in the past when accidents were maybe more frequent but with lower consequences and happening on a network with certainly less dense traffic.

The experience gained by the authors during some investigations, enhanced by the available literature on railway accidents freely available on the web, led to the idea of improving the current organization of Railway Police in Italy to enhance the quality and the efficiency of the investigations conducted during the phases immediately following a railway accident.

As shown, the current frame in fact leads to undesired delays in the restoration of the railway service even when the cause of an accident is clearly identifiable. By the definition of a proper learning programme supported by the Universities or other boards with the requested technical skills, the authors showed the possibility of creation of a competent structure distributed over Italy with limited resources that could lead to consistent savings in terms of time and money.

The authors would like to thank the respective institutions for permitting the publication of this paper. At the moment the proposed project is under crossed evaluation to identify its practical feasibility including funding aspects.

References

[1] Italian Republic, Legislative Decree August 10, 2007, no. 162.

[2] Railway Safety Directive on safety of the Community's railways (Directive 2004/49/EC of 29 April 2004)

[3] Italian Republic, Code of Criminal Procedure.

[4] Italian Republic, Penal Code

[5] Swiss Accident Investigation Board, www.sust.admin.ch, page retrieved on 09.01.2014.

[6] Polizia di Stato website, www.poliziadistato.it/articolo/view/24419 (in Italian), accessed on 09.01.2014