Use of Collected Data in Accident Investigations

Ian Naish P.Eng., M.Eng, MBA

Naish Transportation Consulting Inc.

SUMMARY

This paper describes a wide range of uses for data collected during an investigation to identify causes of a rail accident. Areas covered include infrastructure, operational and equipment issues; and human factors and organizational issues. Case studies will be used to illustrate the results of various analyses performed on the data and conclusions will be made, along with lessons learned.

This paper also shows the uses of the data for recording various kinds of data for use in macro-analysis of rail safety issues. This kind of data can be used for in-depth analysis tied-into a specific investigation, as well as for communication of systemic issues based on the aggregated safety data.

INTRODUCTION

Early in 2013, I was invited to give a presentation on, "making use of collected data", at a rail safety summit in Johannesburg, South Africa. At the time, I wondered why the question was being asked, as it seemed obvious to me that data collection is a prerequisite for investigating accidents properly. However, upon reflection, it did seem possible that people, both investigators and non-investigators, might wonder why particular types of data or information are being collected, or being measured, or why certain identified track, signal or rolling stock components were being examined and sometimes tested to destruction.

This paper is intended to describe the wide range of data collected during an investigation and what can be done with it to advance rail transportation safety (which is of course why we all are here at IRSC Vancouver). It will also describe some case studies; most, but not all, are Canadian.

This paper will describe typical data that gets collected by functional and other areas, both on and off site. Explanations of why the particular data is collected are also made.

WHAT IS DATA?

A fundamental question is: what is meant by the term "data as it applies to accident investigation? The following definitions can help:

i. *factual information (as measurements or statistics) used as a basis for reasoning, discussion, or calculation;*

ii. *information output by a sensing device or organ that includes both useful and irrelevant or redundant information and must be processed to be meaningful ; and*

iii. *information in numerical form that can be digitally transmitted or processed*[1] *.*

Some examples of investigation data that fit into the above:

[1] Merriam-Webster Online Dictionary

Category i includes:

site survey; site photography; accident reports; accident histories; police reports; weather reports; work-rest patterns; inspection and maintenance records; training and supervision records; and medical records.

Category ii includes:

rail traffic control recordings; locomotive event recordings; signal operation records; photographs; witness interviews (electronically recorded); and metallurgical analysis of failed components.

Category iii includes:

locomotive event recorder data; signal event recorder data; photographic data; and other electronic information.

In the business of accident investigation, there is also a fourth category: materials and components. Specific examples of these include: a broken rail at an accident site; a sense and braking unit at the rear of a derailed train; or a destroyed automobile at a level crossing accident site. These can be “seized” and examined as part of an investigation. Essentially, the term “data” might be considered equivalent to what the legal and police professions would call “evidence”.

WHY COLLECT DATA?

There are many reasons to collect data, the most obvious one being that without collecting critical information pertinent to an accident, there is no way any solid conclusions can be made about why the accident occurred and what can be done to eliminate a similar accident in the future. However, a more detailed set of reasons is to:

- establish the chain of events leading up to and after the accident;
- confirm investigative hypotheses;
- identify systemic safety deficiencies;
- assess performance (train crew, roadway driver; vehicle);
- identify and track historic trends;
- compare safety performance between railway companies and countries;
- identify incorrect or false information;
- refute incorrect statements in the media and from other sources; and
- clarify significant safety issues in public enquiries or in court.

Because some data are perishable, the quicker the investigators can get to an accident site, the better. Even then, data may still be lost before investigators arrive. One way to reduce this possibility is for the first people on site (railway officials, police, first responders, even the media) to “freeze” the site and document the situation wherever possible. Non-investigators can then share the information with the investigators upon their arrival on site. Despite this approach, in the case of catastrophic events where first responders are involved in rescue or recovery, or controlling and eliminating fires, or when the site is declared a crime scene, some information will inevitably be lost.

THE SCIENTIFIC METHOD

Most government investigation agencies use the scientific method in approaching investigations. *This involves a method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses: criticism is the backbone of the scientific method.*[2]

SPECIFIC AREAS WHERE DATA IS COLLECTED AND THE REASONS FOR COLLECTION

Infrastructure Data

One of the first things investigators do after arrival at the site (after having introduced themselves to the site commander and getting a safety briefing) is to take a general walk around the area. While doing this, the overall site scene is photographed in order to get an overall sense of the infrastructure at the time of the accident and a record of the property damage and debris field. A formal site survey, usually done by the railway company, will give accurate geographical information, in plan view, on the complete debris field and the exact location of reference points and where the train (locomotives, power cars, wagons, carriages) has come to rest.

In the cases of collisions and derailments, close-up photographs of the point of collision or the point of derailment will record any marks on rails, wheels, switches and damage to equipment and the infrastructure. This information may be critical in determining the accident sequence, as well as if the accident was related to equipment, track, signal or operational issues, or a combination thereof. Track inspection and maintenance records will provide information on the history and condition of the infrastructure prior to the accident. Examining, measuring and recording the condition of the track, for example after a track buckle derailment, can give indicators of the reasons for its failure.

Signalling system and rail traffic control records will allow examination of the signalling sequence before an accident, and any other operational control states. Maintenance records will help determine if there are, or were, any systemic deficiencies in the signal system operation. Records of communications between operations staff and crew en route, prior to and after the accident will also be collected and examined.

Equipment Data

Examination and collection of information on the locomotive(s) on site can yield data on: cab ergonomic layout; structural damage; post-crash condition of running-gear; draft gear; traction motors; fuel tank; crash survivability and crew protection. Fractured components which may have played a part in the accident are identified, recorded and sent for laboratory examination. Historical maintenance data can help identify any specific problems for the particular locomotive or for the same locomotive model in the railway's fleet.

Similarly, collection of information on: the type of railcar (wagon); effectiveness of its brake system; failed components; railcar contents and maintenance records can yield information on defects either specific to the car involved in the accident, or to its type.

Collection of information on passenger coaches will yield information on: vehicle stability; crash survivability; passenger protection; effectiveness of safety signage and equipment; and ease of evacuation.

[2] oxforddictionaries.com (Oxford University Press)

Operations Data

Typical information collected includes details of: the crew; their operating instructions; their work-rest history for the last few days; particulars of the trip up to and including the accident and their training and supervision. Interviews are held with operating crew members and recorded. A locomotive event recorder download will provide information on the train handling along the trip and also provide a validation of the crew's description of the trip. Rail traffic control records will allow examination of communication with the crew en route, prior to and after the accident. Inspection of the locomotive cab may identify issues related to distraction, for example possible cell phone use.

Regulatory and railway requirements are identified and documented which apply to the crew and the train's operation, and include: the applicable federal regulations; operating rules and the railway timetable; special operating instructions; and the crew's daily operating bulletin.

Human Factors and Organizational Data

Data collected in these two areas include: crew medical history; fatigue analysis; workload; communications; situational awareness; error (mistake) identification and the possible explanations for the error. Medical information may be acquired, and impairment tests may be done. Additional information can come from the within the railway organization, such as training plans, the safety management plan and other pertinent records. These records could be, for example, of accidents and incidents, safety goals and risk assessments for significant operational changes.

Witness interviews can yield very good information, but ideally they have to be corroborated by, or correlated with, data from other sources, such as event recorders.

Level Crossing Data

There are certain data specific to level crossings that are not relevant in other types of railway accident. These include: sight lines for the highway traffic / railway traffic interface, in all four quadrants of the crossing; roadway approach alignment and characteristics (road geometry, surface condition, traffic volumes); crossing surface type and condition; signage and signalization; and accident history. Issues such as: limited road signage; crossing signals with burnt-out bulbs or misaligned lamps; crossings with an uneven or rough surface; are all recorded.

Materials Examination / Failure Analysis

Examples of materials recovered on site for later examination include: fractured rail, or rail components; fractured wheels; failed wheel bearings; brake rigging, fractured axles; and drawbars. The challenge for investigators is to determine whether these mechanical failures were an outcome of the accident, i.e. catastrophic failure during the accident sequence, or whether they actually were pre-existing defects and therefore contributory to the accident. Off-site laboratory examination can identify: the origin of cracks; the type of failure, such as progressive or catastrophic; and the reasons for the failure, which can include fatigue, material quality or design.

Environmental Data

Environmental data includes: weather (including history); position of sun; time of day; visibility; wind speed; and track and highway surface conditions (snow, sand, water).

Other Data

During the progress of an investigation, investigators may learn of other safety issues which did not have a causal role in the specific accident investigation underway. However, since they might need to be addressed by the regulator or industry, they may be pursued. Many independent government investigation agencies have the authority to follow up in any area they wish during an investigation. That means that they may look into these other issues, even though industry officials or regulators may consider them either irrelevant or perceive that “the investigators are going on a fishing expedition”.

Secondly, investigations may sometimes only record some of the information gathered, rather than analyse it. This is usually either because it is not the key focus of the particular investigation, or else it cannot be completely validated as a significant safety issue based on the data available. If such an issue is identified, for example at a level crossing, relating to train conspicuity or the audibility of a train horn approaching a crossing, then those facts can be noted in the factual section of a report even if it is not examined in the report’s analysis section. If it is the first time such an issue has been identified, this is a factual “marker”. In the future, other investigations may identify the same type of issue. In-depth analysis of the data can then take place and a systemic safety issue can be identified, partially because of the information obtained and recorded in the previous investigations.

SPECIFIC EXAMPLES OF DATA USAGE

Besides data usage in an individual accident investigation, it can also be used, in aggregate, to explain trends and identify critical safety issues. Analysis of this data can lead to significant decisions on allocation of inspection and audit resources by rail regulators. Industry also has the opportunity to use this data to identify issues and compare performance between railways.

Example 1: Pictorial Depictions of Data

A pictorial example of data: the pie chart shown in Figure 1 depicts the proportion of reportable TSB accidents by category. This chart allows for a quick assessment of relative severity and of frequency of the categories and can be used by rail investigation management to allocate resources effectively and efficiently. Other pictorial examples are bar charts and graphs. These can all be used to show changes over time, as well as to show the situation for a particular year. Data can also be presented in tabular form or as a list.

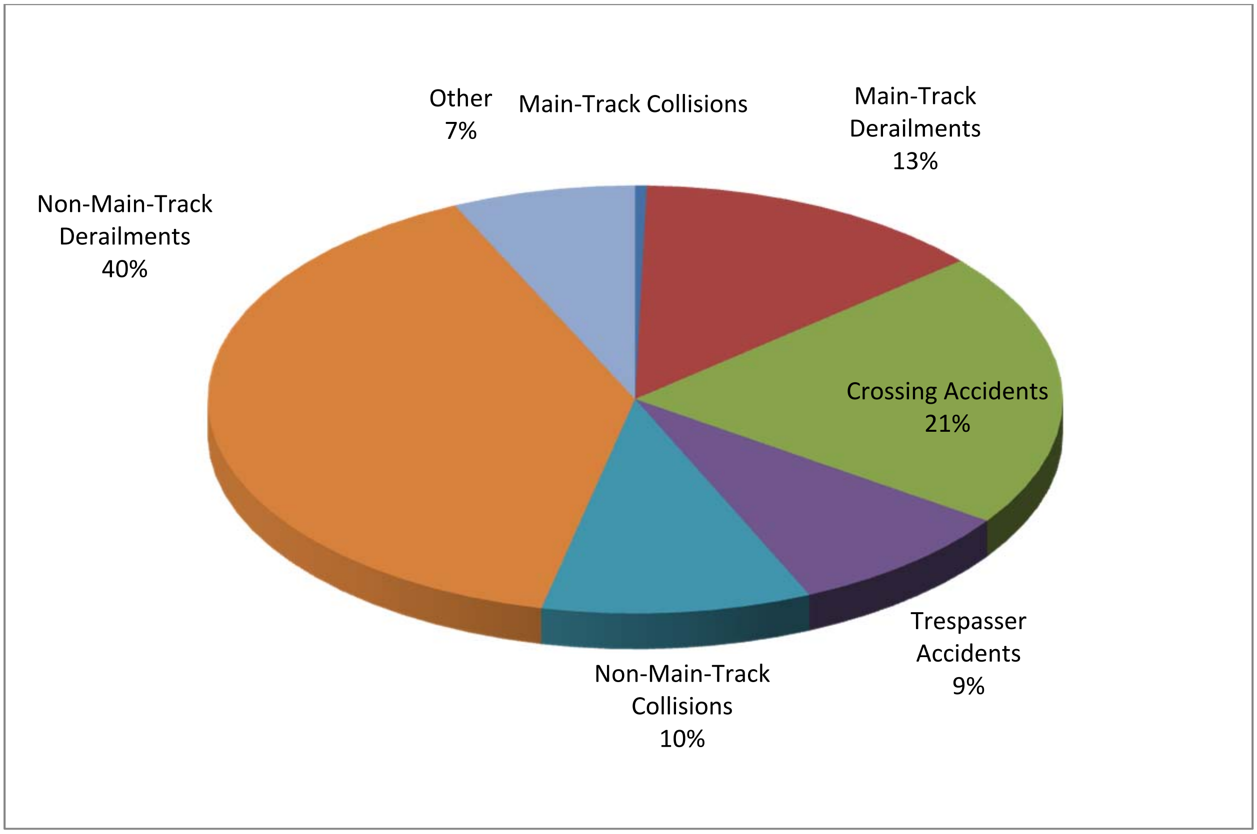

Figure 1: Pie Chart using Aggregate Data for Various Categories of Accident *Source: TSB – Rail Occurrence Statistics*

Example 2: Summaries of Data - TSB 2012 Statistical highlights: railway occurrences

Aggregated data can also be used for reporting on summary statistics. The following example, extracted from the TSB Canada website[3], is an example of written information on aggregate accident statistics:

- *A total of 1,011 rail accidents under federal jurisdiction were reported to the TSB in 2012, similar to the 2011 total of 1,022 and a 10% decrease from the 2007-2011 average of 1,128.*
- *Accidents involving dangerous goods totaled 118 in 2012, the same as in 2011 but down from the five-year average of 147.*
- *In 2012, there were 48 accidents involving passenger trains, down from the 2011 total of 68 and down from the five-year average of 72.*
- *Rail-related fatalities totaled 82 in 2012 (comprising 29 crossing, 49 trespasser, and 4 others), compared to 71 in 2011 and to the five-year average of 76.*
- *In 2012, a total of 204 rail incidents were reported, the same as in 2011 and comparable to the five-year average of 202.*

[3] www.tsb.gc.ca

This published quantification of accidents reported to the TSB is easily available to industry, the regulator, the public and the media and helps provide a sense of the level of rail safety in Canada.

Example 3: Data from a derailment investigation and subsequent macro-analysis work leading to identification of a safety deficiency.

In 2004, a shattered wheel rim on an intermodal train caused a series of broken rails whilst en route, and the train eventually derailed on a bridge approach, with a derailed railcar falling from the bridge and causing fatalities to the occupants of a highway vehicle passing below (Photos 1 and 2). Upon examination of the broken wheel, investigators contacted the major Canadian railway companies to identify how many records they had of similar failures, and whether they involved the same wheel manufacturer. In response to a question of why the TSB was collecting the data, a specific railway was also asked what proportion of the manufacturer's wheels were in their fleet, and what proportion of failures they sustained. This tied-into a hypothesis that one particular manufacturer's wheels had a higher frequency of failure than others. The railway checked its records and found that a specific manufacturer was found to have a large proportion of broken wheel failures, even though the wheels only represented a relatively small proportion of the wheels in service on the railway. As a result there was immediate action taken to eliminate certain of the company's wheels from service in North America. Canadian Pacific also prohibited all of its wheel suppliers from re-using the wheel company's wheels on wheel sets assembled and sold to CPR.

Photo 1: 2004 Derailment of Intermodal Train, Whitby, Ontario *Source: waymarking.com*

Photo 2: Shattered Wheel from a Different Incident (but same wheel manufacturer) *Source: TSB Report R04T0008*

Example 4. Data obtained from the Media used in a Level Crossing Accident Investigation

Because of constant pressure to publish “breaking news”, the media often obtain a substantial amount of documentary data. One TSB investigation in 2001 involved a level crossing accident where a person in a wheelchair was stuck on the crossing and then struck by a passenger train. Fortunately, the victim survived. By the time the TSB’s investigator arrived on site several hours later, the crossing was observed to have good quality planking. However, he subsequently learnt of a local TV station’s video-report from the site just after the accident. The videos recording showed a very poor condition crossing surface, which was found to be a contributory factor in the occurrence.(Photo 4).

Photo 3 (Perishable Data) Image taken from a Media Videotape of Deteriorated Crossing Planking
Source: TSB Report R99S0071

Example 4: Data Obtained by Non-Traditional Means during a Level Crossing Accident Investigation

While there are traditional ways of obtaining and recording data in the three functional areas and in the human factors and organizational areas, there are many examples of non-traditional investigative data that have been used to examine safety issues which can help identify a safety deficiency. For example, in the case of level crossings, there is a wealth of information on the internet which can aid investigators in obtaining data for level crossing analysis purposes. They include: satellite images; Google street view; news articles; research papers; investigation reports; and regulatory requirements from domestic and from other countries. The news media can also provide good background information and images from their reports.

The Google Earth image shown in Photo 3 is of a level crossing and its surroundings. On reviewing accident information for this particular level crossing, where a semi-trailer was struck by a train, investigators wondered how many semi-trailers could be stored at the approach to a nearby highway intersection before blocking the level crossing. No related measurements had been taken at the time of deployment. However, investigators did subsequently manage to obtain recent images from the internet, including the one shown. Photo 3 actually shows a typical semi-trailer negotiating the crossing. This allowed an easy estimation of relevant distances and storage available, as well as identification of a change in the road's horizontal alignment right at the crossing and even speed bumps on the crossing approaches. There were steel factories nearby, and other Google Earth images allowed measurement of the factories' areas and trip generation data from other internet sources allowed an accurate estimation of the vehicular traffic generated along the road.

Photo 4: Example of Data that can be Obtained from Satellite Pictures *Source: Google Earth*

Example 5: Incorrect information and Communications Data Quality

On 27 June 2012 the Saudi Railways Organization passenger train No. 1, en route from Dammam to Riyadh, derailed at a turnout at Al Khurais Junction. The locomotive and all eight passenger cars derailed at 120 km/h at the eastern end of the station. There were 332 passengers on board, four of whom sustained serious injuries.

Sand Issues?

Three investigators had deployed from Dammam to the site. Whilst en route, information came by phone from two of their colleagues that the derailment was caused by sand, as they had seen media photographs showing the rails covered in sand.

Photo 5: Media picture of passenger evacuation, showing communications cable duct cover in foreground. *Source: Saudi Ga*zette/Okaz photos

On arrival at the site, railway officials confirmed to the investigators that sand was not an issue in the derailment. The apparent “rail” in the foreground was actually a communications cable duct. Clearly, this initial information, which could have been very important, was incorrect.

Radio transmission Quality

The train crew had been operating under instructions informing them that they would be continuing along the main track for a planned train meet at the siding. A critical radio message from the signaller to train No1 advising of a change in instructions was unclear and therefore not successfully communicated to the train crew.

Radio communications records from the signaller at the traffic control centre just before the accident were of a poor quality. A few weeks after the accident, investigators contacted TSB Canada, and RAIU Ireland, both of whom made substantial efforts to enhance the voice records. The RAIU’s efforts were successful; they used non-proprietary software to screen-out the recordings’ background noise, with the result that all but one record could be clearly understood.

DISCUSSION

There is always extensive data collected during any rail accident investigation. The data is collected for the purpose of identifying the chain of events before, during and after the accident sequence. The data are then analysed to identify unsafe acts or unsafe conditions related to the chain of safety significant events. From that, and from the results of the analyses of historical records, interviews, and laboratory examination of materials, an assessment of risk (high, medium or low) can be established for a recurrence of a similar event. If the risk is considered high, then a safety deficiency will have been identified which can then be addressed by the regulator or industry.

Additionally, data are used to create archives of safety related information that can be analysed in other investigations, as well as to monitor safety trends. These records can be used to monitor and compare accident performance, both on a macro level and on a railway by railway basis. Records of incidents, which can be precursors of accidents, can be used as early warning systems of bigger safety issues. Reports for each railway can be used to compare safety performance as well as to identify possible under-reporting, using various statistical techniques.

Sometimes investigators cannot collect all the data they would like. Should this happen, they have to obtain information by other means, or accept the gap in information. They can continue with the investigation, but also be prepared to address the identified gap if and when a similar accident occurs in the future. This gap happens quite often, for various reasons. For example, the railway may have moved some equipment/materials to expedite track reopening, or a post-crash fire is destroying, or has destroyed, the evidence or particular witnesses have been non-contactable. Some ways of compensating for this data gap are: hire subject matter experts for their opinions; examine whether alternate means are available to be able to answer the question, and come to a conclusion; do a simulation (managed re-enaction) of the event; or check library sources, including the internet, to search for related information.

When do investigators know when they have collected enough data and done enough analysis? This depends on resources, time and the level of quality required. One possible approach is to apply the *Pareto Principle* or the *80:20 principle*. Applying this to investigations, the approach would be that 80 percent of the safety benefit will come from 20 percent of the issues identified. If investigators just want to address the most critical issues, they still have the option to “put down a marker” in the factual section of the investigation report for some of the other, less critical, issues. They can then dig deeper into these latter issues in other future investigations, where the same issues have been identified.

The no-fault, no-blame, dispassionate approach to an independent investigation can clear-up a host of questions. For example, the chain of safety-critical events does not start with a crew's actions just prior to the accident. Rather, these actions are at the stage of the last failure in a series of failures leading up to the accident. Good data allows identification of problems in a wide range of areas, such as: company policies; industry rules; government regulations; gaps in supervision and training; gaps in safety management systems; gaps in infrastructure design, equipment design and operations; and in standard operating procedures. When this is presented logically and clearly in an investigation report, its publication will contribute to the advancement of safety knowledge and often the taking of positive safety action.

Rail safety in Canada is generally improving, and has been for decades. However, major accidents, such as some very serious recent ones, are a strong reminder that complacency is not acceptable. Light-touch regulation may be in vogue around the world, and it can have major benefits if all participants act in good faith and do the "right thing". But that does not always happen. In the event of a very serious accident, investigators, regulatory bodies and industry might want to ask themselves: could this horrible event have been anticipated? Good data resources and good analysis of the data will always help to answer this question.

CONCLUSIONS AND LESSONS LEARNED

Good quality data is a fundamental requirement for the solid analysis of accidents and for the production of a high quality investigation report. Data collection starts as soon as notification of an accident occurs, and continues until the finalization of the investigation. The sooner that the critical data is available to investigators, the quicker the analysis and establishment of the chain of events and more time will be saved in pursuing the investigation and identifying safety deficiencies.

Should safety critical data be missing, well-trained investigative teams can often find alternate means to fill the gaps in safety knowledge exposed by the missing data. Should alternate means not be available, the data gaps can be addressed in future investigations into accidents where there are similar conditions to the accident where the gap was first identified.

Finally, good quality collected data helps in understanding the rail safety environment and it is an essential building block of a scientific investigation. Data records provide a solid basis for analysing trends and identifying existing and sometimes predicting future safety issues.