

## TECHNICAL SOLUTIONS AND OPERATIONAL MEASURES FOR PREVENTION OF FREIGHT TRAIN DERAILMENT AND MITIGATION OF THEIR CONSEQUENCES

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*Train derailments, especially those of freight trains, are a major concern for all stakeholders involved in the rail transport due to the fact that this type of accidents can have important consequences involving material damages and human injuries or even death. Considering this, in the last period, infrastructure managers, rail undertakings and institutions concerned by the European rail transport safety looked for technical and organizational solutions that could prevent the derailments or limit their consequences, especially in the dangerous goods transports.*

*This paper reveals a general presentation of these types of measures implemented at European level compared to the ones adopted until now for the rail transport in Romania. Starting with the causes of the derailments on a 7 years period in Romania, it concludes with the most efficient implementation of these solutions that proved to be effective on other railway networks.*

**Keywords:** railway, derailments, causes, preventions, technical measures, operational measures.

### 1. Introduction

The study of the derailment and the avoidance of such an event had always an utmost importance due to economic importance and societal impact. Reducing the occurrences of freight train derailment results in cost reduction for railway undertakings and infrastructure managers and increasing of the safety of freight operation as compared to other transport modes.

In this respect, in the last years, many infrastructure managers, railway undertakings and institutions concerned by the European rail transport safety took measures to reduce the number of such events and for reducing their consequences.

Knowing the direct causes of the derailments is the first step for understanding which are the right directions of action to influence the occurrence of such accidents. The paper compares the causes distribution for derailments occurred on the Romanian railway network with the distribution of the same types of causes in Europe railway network and it tries to establish which could be the main directions for reducing the number of derailments in our country.

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## 2. Insight on freight train derailments across Europe and on the Romanian railway network

A study carried out for the European railway network [1] revealed that 37,1% of the freight train derailment are produced by rolling stock causes, 36,2% are produced by infrastructure breakdowns, 25,4% by operational failure and 1,2% by other causes (environment, etc.).

Comparing with the derailments causes on the Romanian railway network [2] for a seven years period, it reveals that the major part of these accidents occurred due to infrastructure breakdowns. If in case of European network, the ratio between the accidents caused by infrastructure breakdowns and those produced by rolling stock is roughly equal to 1, for the Romanian network this ratio increases to 2 and more than 50% of the overall accidents were caused by infrastructure issues – see Fig. 1.

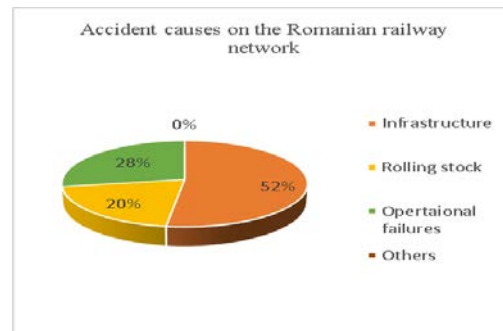


Fig. 1. Categories of derailments causes on Romanian railway network.

## 3. Infrastructure failures, preventive and mitigations measures

It was shown above that the main category of derailment causes includes those related to infrastructure failures. Within this category one can distinguish the following subcategories:

- causes related to track geometry (twist, width, height, cyclic tops, buckles, etc.);
- causes related to superstructure (rail ruptures, fastening, switch, etc.);
- causes related to substructure (subsidence, bridge failure, etc.);
- other.

In Fig. 2 are presented the weights - expressed as a percentage - of the above subcategories of infrastructure failures, for both Romanian and European railway network. It can be seen that the trend is the same and the differences are not important, about 70% of derailments caused by infrastructure failures being connected with track geometry. Therefore  $36\% \times 68\% = 25\%$  of all freight train derailments across Europe and  $52\% \times 70\% = 36,5\%$  of all derailments across Romanian railway network are caused by track geometry or have track geometry as a significant contributory cause.

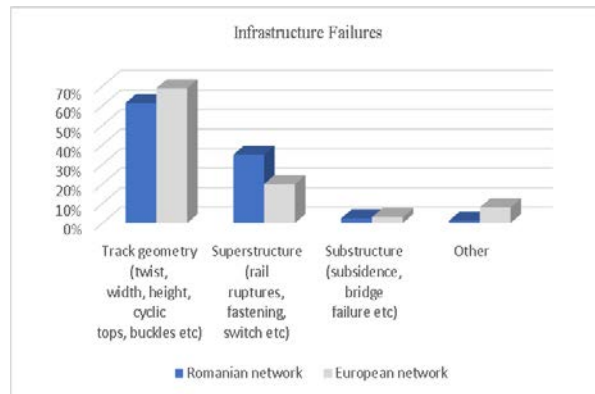


Fig. 2. Infrastructure failures on the Romanian and European network.

The most used measures in the European states to prevent derailments related to infrastructure failures are:

- perform ultrasonic rail inspection of track at sufficient frequency in order to detect rail cracks before dangerous ruptures occur. This is an activity carried out by most infrastructure managers with frequencies depending on rail age and traffic loads [3];
- perform track geometry measurement of all tracks in order to detect track sections requiring maintenance actions. Regular track geometry measurements are carried out by most infrastructure managers. The completeness of the measurements with respect to track coverage at stations, as well as intervals, may vary. Frequency is normally depending on traffic load and on the maximum permissible speed of the track;
- installation of check rails to prevent derailments, especially in sharp curves, in order to avoid flange climbing on the outer rail. Check rails are also used in other conditions and have also wear reducing effect;
- detecting rail ruptures trough track circuit as part of signaling system;
- using of ground penetration radars (Geo radars) to survey conditions of track bed superstructure with regard to quality and water content.
- rolling stock mounted equipment for monitoring of rail profile conditions.

Romanian infrastructure manager is using at this moment only few of these measures: installation of check rails, performing track geometry measurement and performing ultrasonic rail inspection.

In addition to preventive measures, many railway administrations have put into practice mitigation measures as follows:

- existing mandatory requirements for safety rails (guard rails) at bridges and in tunnels;
- battering rams in front of safety critical pillar supports of roof structures and overbridges, in order to prevent the damaging of such safety critical structures by the derailed rolling stock;

- installation of dragging object and derailment detectors;
- installation of deviation points leading to a safe derailment place in high slope descending tracks from marshalling yards and train formation stations.

Romanian infrastructure manager has put in practice two of the mitigation measures listed above, namely the fitting of rail guard on bridges and tunnels and ensuring deviation point in the area with descending steep tracks.

#### 4. Operational failures, preventive and mitigations measures

On the second place as share of the total derailments there are operational failures, that can be subcategorized as follows:

- train loading (overload, skew loading, etc.);
- mishandling of train (overspeed, etc.);
- turnouts (point movement, incorrect setting, etc.);
- train formation and testing (train composition, brake test not performed etc.);
- others (objects under train, etc.).

If across Europe these 5 types of causes are relatively equal in terms of occurrence, the data from the Romanian railway show that the main causes (about 30%) on this category are represented by train formation and testing (train composition, brake test not performed, etc.) – see Fig. 3.

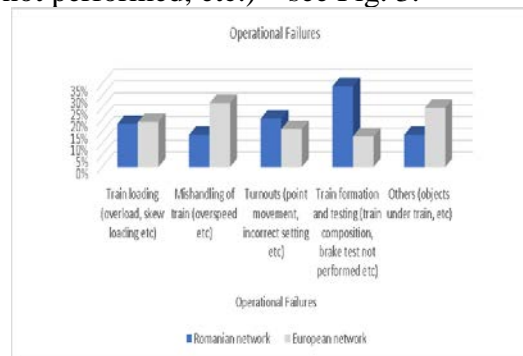


Fig. 3. Operational failures produced on the Romanian and European railway network.

The common measures implemented in Europe for preventing these types of occurrences are:

- qualified and registered person responsible for loading. The person must show sufficient competence and be registered by the train operator;
- using of wagons equipped with a balance to detect overload in visual inspection;
- national regulation which applies to long freight train that impose, for locomotive and first wagons, to put brakes exchanger device in position G, with the aim to limit the compression forces of the train when braking with the pneumatic activated train brakes.

The last measure is also in place for the freight trains that are operated on the Romanian railway network.

Mitigation measures are also adopted by railway undertaking and infrastructure managers:

- higher degree of separation of passenger and freight traffic to separate lines;
- restrictions on freight traffic - in general, or on hazardous materials transport - in special, through certain busy passenger terminals and/or underground stations to restrict traffic and limit the consequences of a derailment;
- requirement for activating of warning lights in driving end of train;
- emergency communication connection between trains and traffic control can reduce the time from derailment to train stop and hence reduce consequences.

None of these preventive measures for reducing operational failures has been implemented in Romania.

## 5. Rolling stock failures, preventive and mitigations measures

The third category of derailments causes is linked to rolling stock failures. In graph of Fig. 4 are presented the main subcategories of rolling stock failures that have produced derailments on the European and Romanian network.

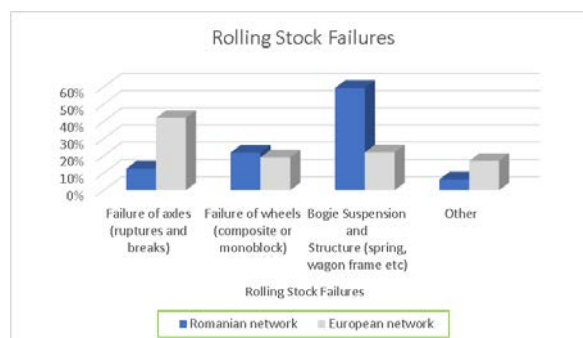


Fig. 4. Rolling stock failures produced on the Romanian and European railway network. These main subcategories are:

- failure of axles;
- failure of wheels;
- bogie suspension and structure (spring, wagon frame, etc.);

Comparing the results from Romania and Europe it can be noticed that the proportion of failures of wheels is relatively the same. On the other hand, significant differences are observed regarding the failures of axles, bogie suspension and structure. Measures adopted across European countries to prevent this type of failures consist of:

- flange lubrication of locomotives in order to provide necessary rail/flange contact lubrication with the aim to reduce the friction available for wheel flange climbing[4];
- replacing composite wheels with monobloc wheels because composite wheels have more complex inspection and maintenance requirements and seems to have a higher failure rate causing derailments;
- replacing metal roller cages in axle bearings by polyamide roller cages. The reason for the replacement was a number of derailments due to hot axle boxes and shearing of axle journals prior to the decision being made (if the wagons have been monitored with hot axle boxes detectors). The cause of many of the failures was wheel damage. The polyamide cages were considered less prone to failures due to vibration impact.
- replacing existing axles with stronger axles or axles with improved material properties with regard to crack initiation and crack propagation. On this respect it was developed EURAXLES [5], a R&D project that aims to bring the risk of failure of railway axles to such a minimum level that it will no longer be considered as a significant threat to the safe operation of the European interoperable railway system.
- increasing the use of central coupler between wagons in fixed whole train operation. With an integrated draw gear and buffer function in a central coupling the rolling stock side buffers become superfluous. This will reduce side buffer loads and will reduce the risk of derailment due to buffer locking and couples that are too loose or too tight between wagons;
- increasing the use of bogie wagons instead of multiple single axle wagons with a long wheelbase [6];
- installing disc brakes instead of wheel tread brakes for new rolling stock, the major motivation being less heat activation of wheels, which may reduce derailment risk;
- securing brake gear located in the underframe of the wagon to ensure that braking components that become loose does not fall to the ground and cannot cause a derailment;
- regular greasing and check of fastening of rolling stock buffers to reduce risk of a buffer falling off and causing derailment;
- ultrasonic inspection of wheelsets.

Some of these measures have been adopted also by the railway undertakings that are present on the Romanian market. Most of the electrical locomotives that are hauling trains in Romania have flange lubrication for reducing friction between wheel flange and rail and for reducing the energy used on curvy track sections. Other measures that were used for long time ago were regular greasing and check of fastening of rolling stock and regular ultrasonic inspection of wheel sets.

The high proportion of bogie suspension and structure wagon frame failures for wagons that are running in Romania can be explained through poor maintenance actions performed by the keepers of the rolling stock and, on the other hand, by the poor state of the infrastructure that influences the rolling stock condition and is increasing its failure rate.

## **6. Possible future preventive and mitigation solutions for Romanian railway network**

Analyzing the causes that had the biggest contribution in accident occurrences, it can be noticed that those related to track geometry and superstructure of the track cover almost 50% of the accidents investigated in Romania in the last 7 years. This is an important indication about the state of the Romanian railways and of the maintenance quality. It is to be emphasized that track geometry is one of the crucial track condition parameters, closely related to many other degradation phenomena.

Starting for this point it could be identified few technical solutions that can be used for preventing such accidents or for reducing their number. Of course, the analysis must also take into account the financial implications of the implementation of these measures, given the limited possibilities of the infrastructure manager from this point of view.

Reanalysis of curves and in other areas where a better guiding of the wheels is necessary and installation of check rails to prevent derailments can be one of the solutions.

Perform track geometry measurement of all tracks with electronic systems that can determine the accurate position of track section and continuously work with printed outputs are another measure that could enable retrospective checking and evaluating its repeating and developing at the same places in order to detect track sections requiring maintenance actions. In particular it can establish processes and safety conditions for track measurement under load. The frequency of recording has to be such that the information provided allows to monitor trends and rates of deterioration with a high degree of certainty, thus enabling to identify the need for work (tamping, rail defect repair/removal, etc.) sufficiently far in advance to plan resources and access within the normal planning timescales, avoiding the need for short-term intervention which is disruptive to trains and passengers.

With about 12% of total number of derailments, on the second place there are derailments due to bogie suspension and structure failures (spring, wagon frame, etc.). The third place, with about 10% of all derailment cases are the category of causes related to operational failures, train formation and testing. Causes for this high rate of operational failures can be explained through deficiencies in the safety management system of the railway undertaking.

It can be noticed that ‘hot axle box and axle rupture’ that in Europe are one of the first cause of the derailment does not take the lead in this ranking [7].

To limit the type of derailment placed in 2nd and 3rd place the actions for prevention and mitigation can be focused on organizational measures such as:

- inspect axles of freight train rolling stock according to EVIC (European Visual Inspection Catalogue) [8];
- requirement for double check and signing of safety-classified (S.-marked) maintenance;
- traffic controllers and drivers should not be allowed to override detector alarms;
- awareness program for rolling stock maintenance. This measure may serve to address the problem of poor maintenance standards of rolling stock. This may include training aimed to focus on the main rolling stock maintenance derailment causes.[9].

## 7. Conclusions

It is obvious that the main causes for derailments in Romania are in connection with the state of infrastructure and also there is a direct relation between the last two causes, because operational failures that appear in trains preparation performance lead to failures on bogies suspension, so this type of actions influences about 22% of derailments cases.

So, to decrease by about 75% the derailments that occurred on the Romanian railway network (according to the presented statistics), measures have to focus on the track geometry and on rolling stock inspections, and a few of them have been exemplified in this paper.

## REFERENCES

1. DNV Study on freight train derailments A. Mecke, I. Lee, J.R. Baker jr., M.M. Banaszak
2. [www.agifer.ro](http://www.agifer.ro) Romanian Railway Investigating Agency website ,
3. Optimizing Ultrasonic Rail Defect Inspection to Improve Transportation Safety and Efficiency X. Liu , C.T. Dick The Second T&DI Congress, June 8-11, 2014 Orlando
4. EURAILmag Business & Technology /// ISSUE 30, Pages 48-52
5. EURAXLES – 265706 – Final Report , <http://www.euraxles.eu>;
6. Dynamics Of Railway Freight Vehicles Iwnicki S.D., Stichel S., Orlova A., Hecht M. - European Project SUSTRAIL on rail freight systems
7. Cost effective future derailment mitigation techniques for rail freight traffic management in Europe, Dewan Md Zahurul Islam, Konstantina Laparidou, Arnaud Burgess, ELSEVIER, September 2016, Pages 185-196
8. *European visual inspection catalogue (EVIC) for freight wagon axles, Joint Sector Group for ERA Task Force on wagon/axle maintenance*
9. European Railway Agency, *Prevention and mitigation of freight train derailments at short and medium terms, 2012.*