

# **Analysis of Major Causes of Accidents in Egyptian National Railways and Cairo Metro Lines**

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**Abstract:** In this paper a study for the major causes of accidents in Egyptian National Railways and Greater Cairo metro network that occurred in the last decade from year 2000 to year 2010 is presented. It is noticed that rates of accidents during that period especially from 2006 to 2009 is very high and the nature of accidents is also very catastrophic. Therefore, annual frequencies of two major types of accidents have been selected to be studied in detail. It is found that signal passed at danger is a major cause of many severe and fatal accidents during that study period. The accidents of that type have resulted in many fatalities, injuries and deterioration of different railway equipment. The second type of accidents is fire of rolling stocks which had higher records as well as consequences of few of them were very catastrophic either on passengers or on the equipment. Detailed analysis has been carried out for causes and impacts of those types including fatal and non fatal accidents. Also, an evaluation of all causes which affect badly on safety of the running trains in tunnels and on ground surface of these lines have been carried out in this paper. Some important standards and regulations of fire of rolling stocks including "British standards", "draft of new generation for European standards which will be issued by end of year 2012" and "Guidelines of Safety and Service Quality Measures for Transportation by ENR" are presented in this paper. Lessons that have been learnt from the most severe fire accident that had been occurred in February 2002 and recommended by the technical inspection committee have been presented. Conclusion and recommendations that contribute in reduction of those two types of accidents have been introduced at the last chapter of the paper.

## **1- Introduction**

The Egyptian National Railways (ENR) is considered most important foundation in the field of passenger transportation in Egypt and in the Middle East since more than one hundred and fifty years. Nowadays Egypt has 28 rail lines, where their total length is about 9435 km and the annual No. of passengers has come to 800 million [1]. Also, it was the safest mode of transportation during that long period, whereas safe transportation of passengers was the key business objective. In comparing with road transport mode and for the same traffic, the risk of a fatality occurring is eight times greater in road than in rail transport, whereas the risk of an injury is 200 times more likely to occur on a roadway than on rail[2].

According to statistics that have been carried out by U.S. Department of transportation, Research and Innovative Technology Administration in year 2009, ratios of rail accidents and casualties represent only about 0.07 to 0.38 % from the total no. of accidents and casualties respectively. Also, it is noticed that rate of casualties per one accident is 2.26 in case of rail mode, whereas this rate is higher than rates of all other transport modes [3].

Considering the rate of casualties per one accident that had been accounted for ENR rolling stocks last decade, it had been found at range of 3.4 to 4.5 [1].

Safety is the key performance index which the top management need to monitor and take preventive steps based on trends of accidents which are the manifestation of some of the unsafe practices on the system. At the last decade, ENR had seen a series of severe accidents,

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whereas the number of fatalities reached more than 6000 persons as well as many other injuries. The catastrophic consequences of rail accidents (e.g., fire of a train in 2002 near Al-Ayat town, collision of two trains at Kalyob station in 2006) not only resulted in loss of life, severe of property damages, but also left the public with a lack of confidence in using the rail network.

The Safety Unit of ENR has classified the accidents into 14 divisions according to the accident causes and nature (e.g., signalling passed at danger, fire on train, derailment, collision of two trains, collision of train with a passing vehicle on the level crossings, ... etc.).

This paper discusses the safety performance of ENR during the last decade from year 2000 to year 2010, where the causes of major accidents that have severe impacts are recorded, studied and analysed. Regarding the classification of accidents, human factor that has led to signalling passed at danger (SPAD) and over-speeding, played a major cause of many fatal accidents on different locations of the ENR network. Therefore, this type of accidents will be studied in detail to find out the main causes as well as the pad impact. Although, Automatic Train Control devices (ATC) have been installed on about 85 % of the ENR network and on all line 1 of Cairo metro to minimize the human factor in operation of the trains, they do not work properly due to cancelling their activity by the drivers or bad maintenance. Regarding the influence of the Automatic Train Control devices (ATC) on the operation, the direct relation between SPADs and disordering of activeness of the devices by the drivers will be discussed.

The second type of accidents on ENR network that has been recorded, studied and analysed in detail is the fire of rolling stocks, whereas it is classified into two different divisions according to the degree of severity and fatality. Also, fire accidents principles in metro lines including tunnels and station buildings have been mentioned. The fire regulations in England (BS 6853) as well as a draft of the new European standards for rolling stocks (pr EN 45545) that will be issued by end of 2012 has been introduced.

Results of the analysis, lessons that have been learnt from both the human factor and fire accidents will be concluded and recommended by end of the paper.

## **2- Human factor**

Human errors in railways are defined as errors made by humans in traffic operation as well as maintenance of infrastructure and rolling stock which leads to an immediate dangerous situation or accident. This paper concentrates on train driver`errors such as: signal passed at danger ( SPAD) incidents, overspeeding, conflicting train route settings that are typical examples of human errors which lead to dangerous accidents in railways and especially in subways. The work of the train driver is demanding and full of responsibility as he is in charge of both safety and punctuality, a job which requires a lot of concentration and alertness. Irregular working hours, stress and fatigue including distressful noise levels, vibrations and uncomfortable cab climate, are main causes of non concentration and monitorless of the train drivers, hence collisions of trains occur [4].

### **2-1 Main Causes of Signal Passed at Danger**

Trains passed a signal displaying a stop aspect is a very dangerous occurrence with the risk of an immediate conflict with another train. SPAD occurrences have traditionally been relatively frequent incident. This is to be expected as a SPAD can be caused by a single failure of a driver who approaches hundreds of signaling points every day. Fortunately, it is

only a small fraction of all SPAD occurrences that leads to real accidents, but when they occur they are often of a catastrophic nature [5].

A SPAD can occur due to several reasons:

1. Misjudging the effectiveness of the brakes under particular circumstances.
2. Over-speeding in relation to braking performance and warning signal distance.
3. Broken driving sequence (i.e. the train stops to exchange passengers between the warning signal and the main signal and the driver forgets the signaling aspect during the stop due to distraction).
4. Misjudging of which signal applies to the train in question (i.e. the train proceeds based upon observation of a signal that was meant for another train).
5. Misunderstanding of signaling aspect.
6. Signal not seen due to bad visibility.
7. Complete oversight or disregard of a signal.
8. Driver is unconscious or falls asleep.

Recently, automatic train control system (ATC) has been introduced to minimize the number of SPAD's occurrence. It has contributed in reducing of accident rates over the years. In spite of installing such modern devices in about of 85% of rail network of ENR [6], many SPAD accidents are still occurring and many of those devices were broken-down as noticed from the statistics in Table 1[6]. Comparing the figures, it is noticed that the rate of breakdown of the devices has been raised up, and the record at year 2010 is also three and half times the records of the twice former years. The main reasons of that increasing in the breakdown are the lack and bad maintenance, lack of spare parts and deliberating making them inactive several times.

Table 1: Statistics for ATC breakdowns during years 2004 to 2010 [6].

Year	2004	2005	2006	2007	2008	2009	2010
No. of operation breakdowns of ATC devices	224	166	195	252	361	383	1390

In Table 2, statistics for SPAD accidents that have occurred in the period from 2000 to 2010 are shown [7]. It is clear from chart in figure 1 that No. of accidents has increased gradually from the minimum value (8) in year 2004 to reach peak value (44) in year 2008 and continued high during year 2009. The SPADs were coming down in year 2010 to more than half of the records of the former three years as the drivers were subjugated to many restricted control rules despite increasing No. of ATC breakdowns [7]. The second reason for decreasing the No. of accidents was cancellation for one hundred trips on the rail network. It is also noticed that period from 2007 to 2009 is considered the worst for accidents due to SPADs.

Table 2: No. of accidents due to SPAD on ENR Tracks from 2000 to 2010[7]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
No. of SPADs	14	14	15	10	8	15	14	24	44	40	17

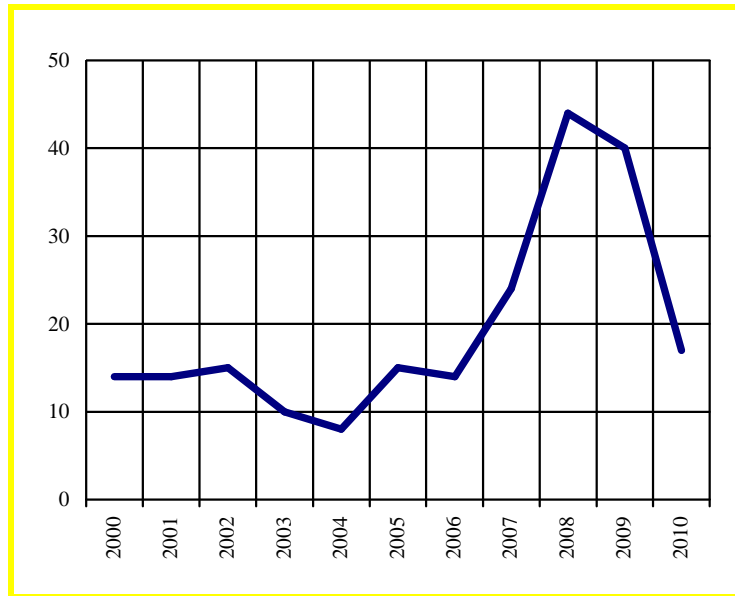


Figure 1: Frequency of SPADs during the period from 2000 to 2010

Referring to the reports of the Central Department for Operation Control and Supervision in ENR, it is found that the main reasons of those SPADs are as follows [7]:

- Opening of the automatic car air braking valve, on purpose by a passenger.
- Driver is unconscious or falls asleep.
- Complete oversight or disregard of a signal.
- Over-speeding in relation to braking performance and warning signal distance.
- Inactivity of the ATC devices due to bad maintenance or repealing them deliberately by the drivers.

A major accident had been happened on 24 October 2009 on the main line of Cairo – High dam. A collision of a coming train No. 188 with another stopping train No. 152 on the same line at km 80.100 close to Kafr Ammar town, had been occurred in spite of providing the two trains with ATC devices. This accident resulted in the following impacts [ 8 ]:

- Stopping of train operation on the two main lines (Cairo- High dam).
- Twenty nine injuries.
- Death of eighteen passengers.
- One hundred meters of the tracks had been deteriorated.
- Damaging of the locomotive and the next carriage of the coming train No. 188.
- Damaging of three carriages of the stopping train No. 152.

The main causes of that accident, as stated in the report that had been prepared by the responsible technical inspection committee, can be summarized as follows [8]:

- Neither the driver of the stopping train No. 152 nor his assistant has told the operation supervisor or the signalman by the incident which led to their train stoppage on the main line.
- They did not make any action to try to stop the train No. 188 before the collision.
- No body was found at the central Observation tower to receive the telephone call of the local observer at Al-Reka tower.
- The driver of the coming train No. 188 had canceled on purpose the activity of the ATC device, however he passed the yellow and red signals with the full train speed (104) km/hour.

## **2-2 Over-speeding**

Another type of train driver's error that has led to numerous accidents is failure to reduce the train speed according to relevant route information for the train. The likelihood of over-speeding and the consequences in that respect depends upon the type of speed restriction and the circumstances around it.

The type of speed restrictions requiring driver response as seen from the train driver's side are:

\* ***Permanent speed restrictions*** due to track curves or other permanent infrastructure conditions which are permanently present on that particular track section

\* ***Temporary or emergency speed restrictions*** due to track maintenance work or temporary track deficiencies (e.g. stability problems, frost heave or risk of sun-curves). The temporary speed restrictions are normally announced in circulars to the drivers ahead of implementation, whereas emergency restrictions can be introduced at a short notice.

\* ***Conditional speed restriction*** due to train route setting at a station or junction and the signaling aspect displayed in that respect.

As an example for the serious impact of over-speeding which results in SPAD is the collision with the buffer stop that had been occurred on 19 December 2007 in Helwan terminal station on Cairo metro- line number1. Analysis of the accident's report refers that cause of accident is passing of the train through the station with a speed over the decided (15 km/hour). Also, the ATC device was found repealed on purpose by the driver [9].

Another major accident due to over-speeding which was accompanied with SPAD is the collision of the passenger train No. 808 with the rear car of the passenger train No. 344 at Kalyob station on 21/8/2006. The accident resulted in the following serious impacts [10]:

- Death of 58 passengers including the driver and his assistant of train No. 808.
- One hundred forty passengers had been injured.
- Full damaging and derailing of the two rear cars of train No. 344.
- Full damaging, derailing and completely firing of the locomotive of the train No.808.

According to the report of the inspectors dated 6/9/2006, the main causes of the accident are as follows [10]:

- The speed of the train No. 808 was higher than the maximum allowable speed which should not be more than 120km/hour.
- Due to the over-speeding, the driver of the train No. 808 could not control the train's speed, thus a SPAD for the red signal (Semaphore No. 34 up) had been occurred.
- The ATC device of locomotive of train No. 808 was not properly working.

## **3- Fire Accidents**

Fire safety is an area of particular interest for modern railway technologies, as well as for conventional intercity and commuter trains. While the historical fire record has been very good and few serious passenger train fires have occurred in ENR, minor incidents could develop into potential life-threatening events. However, fires are the greatest single risk affecting modern railways, especially in tunnels of metro lines. Tunnels present what is

arguably the most hazardous environment, from the point of view of fire safety, those members of the public ever experience.

### **3-1 Fire Accidents Classification**

There are many well-established ignition sources which on vehicles include; matches, cigarettes and other smoker materials; children playing with matches and lighters; cooking equipment; self-heating of specific materials; faulty mechanical equipment (such as brakes, axle boxes); mechanical sparks; faulty electrical equipment (such as motors); electrical sparks; and deliberate fires (arson).

More simply, and more relevant to the railway industries, types of ignition may be categorised as Accidental, Deliberate or Consequential. Deliberate fires include, amongst others, vandalism, arson, military or terrorist action. Consequential fires follow events such as crash, collision, explosion, or structural collapse. In these latter fires it is assumed that some or all of the fire safety systems, active, passive or procedural, are damaged or otherwise inoperable. In the tunnel environment, such incidents may also affect any in-tunnel safety systems.

On passenger carrying trains the greatest risk is assumed to be deliberate ignition; vandalism. Statistics show that around 65% of all passenger train fires have been the result of arson attacks. Although the railway industry assumes that deliberate fires are the most likely, most deliberate fires in trains are acts of vandalism and are consequently of limited severity [11].

### **3-2 Fire Development**

The growth and development of a fire will be influenced in its early stages by the type of fire. Accidental fires usually start off small and can take some time to grow. Occasionally they will start as smouldering fires, which may produce little heat but highly toxic smoke. Deliberate fires will often involve a more rapid initial growth. Consequential fires may be very rapid, especially if the event allows for a rapid release of fuel and often with an unrestricted supply of air.

The deliberate fires assumed by the rail industry are considered to involve a fairly large initial source, such as crumpled newspaper, and that this fire spreads to furnishings, fixtures and fittings. Some consideration is given to "brought on" items, in particular baggage, and refuse, some of which can burn very easily. The general approach is to ensure that the materials in the vehicle are such that a small fire source (1 kW) will have no effect on tenability, that a larger fire source (10 kW) will cause conditions to become untenable only on a time scale long enough to permit escape, and that the largest fire source (100 kW) is unlikely to bring the vehicle to flashover [11, 12].

### **3-3 Analysis of Fire Accidents for ENR Rolling Stocks**

Train fires are important, but are so infrequent that they cannot sensibly be statistically analyzed on their own. The records of all fire accidents that shown in Table 3 [13]; include fatal and non fatal accidents. A fatal train fire can pose a significant risk to both passengers and train-crew or burning of rolling stocks. However, the accident at Alayyat town in February 2002 demonstrates the possible consequences in such cases. Fortunately, such

serious train fires are very rare, whereas four fatal accidents had been occurred along the ten years period.

Table 3: No. of fire accidents for rolling stocks of ENR from 2000 to 2010 [13]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
No. of all fire accidents of rolling stocks	33	31	47	42	34	33	126	200	190	88	55
No. of fatal accidents	-	-	1	-	-	-	1	1	-	1	-

**3-3-1 Analysis of causes of Non Fatal Fire Accidents**

Analyzing of accidents that represented in Figure 2, it is noticed that frequencies of accidents have increased gradually in year 2005 to reach the peak value in year 2007 and continued high in year 2008. The frequency has gradually decreased from year 2008 to reach minimum value in year 2010. The period from 2006 to 2009 is considered the worst for accidents due to fire.

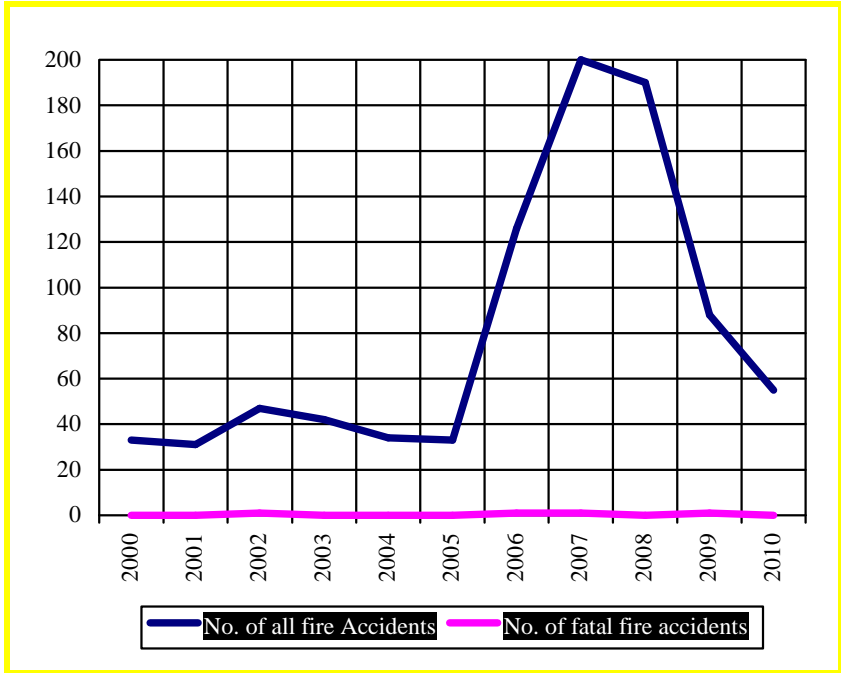


Figure 2: Chart for fire accident frequency from 2000 to 2010

It is concluded according to official reports of ENR [13]; that most of fire accidents are not fatal, however their technical causes are as the followings [13]:

- In-adequate maintenance that resulted in fuel leakage and sparks in brake blocks
- Age.
- De-gradation of components.

**Brakes** are included within 'Technical causes' although it is appreciated that some may be attributable to non-technical reasons, i.e brake tests not properly carried out resulting in overcharging problems on certain train/vehicle types. The absence of positive information in this respect prevented more detailed analysis.

**Electrical fires** are much more predominant in the older vehicles as technically reported by ENR. It is not possible to determine whether the fires are due to:

- (a) the age of components or wiring - such factors would give cause for concern over the safety of other vehicles of similar vintage.
- (b) inadequate maintenance, which would raise issues associated with engineering acceptance and maintenance plans. In the case of (b), this is an issue that is raised under specific classes of carriages and in relation to fires due to debris/litter/dirt.

**Mechanical fires**, a large number of mechanical fires occurred in the engine exhaust system with a build-up of fuel oil (following long periods of idling) being ignited by hot exhaust gases. The fires usually extinguished themselves when the engine was shut down. Mechanical and electrical failures account for the largest numbers of technical cause fires on diesel locomotives. Very rarely does fire spread to other parts of a train but, in the case of diesel locomotives, serious fires can develop despite the presence of automatic extinguishers.

### **3-3-2 Analysis of causes of Fatal Fire Accidents**

The most severe and mishap fire accident that had occurred on 20 February 2002 for the train No. 832 during its running on the up line from Cairo to Aswan has resulted in 361 deaths and 66 injuries. According to the technical inspection report [14]; the main observations and causes of that accident can be summarized in the following points:

- The fire starts at the rear of the 11<sup>th</sup> car.
- The fire likely source was a direct flame source that met many flammable materials.
- The cars were manufactured from flammable materials that assisted in very rapid fire flow.
- The fire temperature reached 1200° C.
- The train continued running with 90 km/hour speed for 12 to 15 minutes after starting of fires, afterwards it stopped at km 74.500 when the driver received an order from the block's supervisor.
- Seven cars have been completely burnt.
- There were not any extinguisher's units in the burnt cars.
- Nobody was able to use the emergency brake because of the passenger's crowd.
- There were not any communication's units with the train's crew.
- The train was not provided with fire alarms or smoke detectors.
- The cars were not provided with emergency doors or windows.

Analyzing the points that mentioned above, many common factors have been found to cause that severe accident. Also, it was clear that safety standards or regulations have not been applied; however lessons that have been learnt from the accident will be introduced hereafter at the recommendation chapter.



The second severe fire had come out from the collision of passenger train No. 808 with the rear car of the passenger train No. 344 at Kalyob station in 2006. The collision led to agitation of fire at the locomotive No. 2110, whereas it was completely damaged and burnt [10].

The third fire on train had occurred on 8 April 2007 in Tanta station yard. The fire started from the first passenger carriage that was behind the locomotive and expanded to the next two carriages. Fortunately, the fire has been started just after coming down of all the train passengers. According to the official technical report, the cause of fire had not resulted from problems in the train itself, but it was due to cigarette that thrown on a seat by a passenger [15].

On 15 November 2009 the fourth fatal fire had occurred in 2 cars of train No. 913 during stopping in Berket El-Saba station yard. All passengers have jumped down from doors and windows of the train. According to official technical reports of ENR, the cause of the fire was electrical spark that had generated from an air conditioning unit [16]. The results of the accident were as follows:

- Two cars had completely burnt.
- Some passengers had been suffocated as a result of toxic emissions.
- No deaths.

### **3-4 Fire Safety Principles in Subways**

The Discussions hereafter gives an over view of the safety principles which are applied for subway projects along the interstations and the stations [17].

#### **3-4-1 Inter-stations**

For inter-station distance between 400 m and 800 m:

A fire hydrant will be installed in the tunnel with connections in the tunnel every 100 m.

- The inflow connections of the fire hydrant at ground level will be installed at less than 60 m from a road access.
- Walkways will be installed in both sides of the tunnel
- The autonomy of the emergency lighting system will be at least 1hr.
- The ventilation system will be capable of producing an air velocity in the tunnel of more than 1.5 m/s.
- The fire resistance of the fans will be of 200<sup>0</sup> C in two hours.
- The ventilation system will be powered by separated power sources.
- It will be possible to command manually from a station the smoke exhaust system of the upstream tunnel and the downstream tunnel.

For inter-station distance between over 800 m an emergency access shaft is implemented.

The shaft contains [17]:

- Staircase of two unity of passage
- Fire hydrant
- Pressurized lobby with ½ hr. fire proof doors
- Area of 25 m<sup>2</sup> between the lobby and the staircase

- Shaft for the access of the fire fighting equipment if the tunnel is deeper than 15 m
- Lift if the tunnel is deeper than 28 m

### **3-4-2 Stations**

The main requirements for the safety measures are the following [17]:

- The station has to be split into zones equipped with an independent extraction and blowing unit, so that in case of fire, the burnt area is put in depression and the other zones in over pressure. Three distinct areas are taken into account for stations:
  - Platforms level
  - Intermediate level
  - Ticket hall level
- For each zone the air renewal ratio has to be at least 15 volumes per hour.
- The smoke extraction fans have to be able to be operated for 1 hour at 400° C and are powered by two different sources.
- It shall be possible to command manually the smoke exhaust system.
- The control equipment of the smoke extraction system should respect the latest standards issues for that concerns.
- Ventilation ducts should be made of non combustible material.
- The ducts, metallic parts, necessary to the connection of fans to the structures should be as fire resistant as the fans.

In addition, the following safety measures should be applied:

- Lobby between the public area and the technical premises
- Sizing of the corridors
- Emergency means
- Fire fighting means ( fire hydrant if the platform surface is above 1000 m<sup>2</sup>)
- The main structure, the floor and slab of the stations should have a fire resistance level of two hours ( if there is no building above the station)
- Mural coatings and ceiling coatings should be low flammable.

For rooms with important risks of fire whose are mainly the LPS, the substations and the store rooms of more than 15 m<sup>2</sup> :

- Floors and walls should have a fire resistance level of two hours.
- They should be isolated from the public area by a lobby area with a fire resistance level of half an hour.

#### **For ducts and pipes:**

- Other ducts and pipes beginning or ending in premises with risks should have the same fire resistance as the walls or floors of the premises.

### **3-4-3 Tunnel Configuration**

The configuration of the tunnel is dependent on the type of rolling stock to be used and the means of evacuation to be employed. The choice of tunnel concept for double tracked rail lines has been given much attention. Two alternative tunnel concepts are discussed in a safety perspective [18]:

**1. Single bored tunnel**, i.e. two parallel tracks in the same tube with escape ways to open air through the tunnel portals or through intervening cross cuts or specially designed escape ways.

**2. Twin bored tunnels**, i.e. two parallel tubes with one track in each with intervening connections between the two tubes equipped with fire doors or smoke locks.

From a fire safety point of view it has in general been argued that twin bored tunnels are safer than single bored tunnels, and that new tunnels therefore should be built according to a twin bored concept. Twin bored tunnels with frequent intervening connections have some obvious safety advantages, but also some disadvantages, which are not equally obvious. Each bore of a double bored tunnel has in general a much smaller cross sectional area than a single bored double tracked tunnel. The larger cross-sectional area is an obvious advantage.

Twin single-track tunnels equipped with modern signalling systems may have advantages for railway safety compared with double-track tunnels in that the risks of collisions resulting from a train derailment between trains travelling in opposite directions are minimized. Where twin single-track tunnels are provided, they will normally aid emergency ventilation arrangements with the non-incident tunnel providing a safe refuge.

### **3-5 Fire Safety Standards and Regulations**

As a result of the severe and catastrophic consequences of fires of rolling stocks that had been occurred, ENR has requested Cairo University to prepare guidelines for safety and service quality measures for transportation by railways. These guidelines that have been issued in September 2004 include safety measures against fire of rolling stocks. Some of the very important measures are summarized in the following points [19]:

- All materials that either used in manufacturing of new passenger's carriages and cabins of locomotives or used during heavy repair of them should pass all required testing of ignition characteristics and smoke emissions.
- All active steps should be taken into consideration for design of passenger's carriages to be nonflammable and to be very safe against fire including detections; however they should allow safe evacuation for all passengers and train crew.
- Any part of the train that may be a source of ignition and that need measures against higher temperatures should be identified. Also, a fire detector should be installed for that critical part.
- ENR should develop and take the necessary actions to assign written performances and steps for testing and maintaining of all fire fighting systems and safety equipment on the passenger's carriages.

Also, the main railway fire safety standard in UK is the British Standard Code of practice for fire precautions in the design and construction of railway passenger carrying trains, BS 6853 [20]. It covers "railway vehicles comprising or forming part of passenger carrying trains", and applies to new vehicles and to substantial changes to existing vehicles. The Code is essentially an "engineering" guide. These standards have defined requirements or objectives based on [20]:

- Material properties, including flame spread, ignitability, heat release, smoke emission, and toxic emission of materials/composites.

- Management of electrical and mechanical design.
- Management of fire resistance (fire barriers).
- Management of fire detection and suppression systems.

Some other countries, including, for example, France, Germany and UIC, have similar codes, and although all have differences, they all are seeking to achieve very similar objectives in protecting passengers. A new harmonized European standard for fire protection in railway vehicles is currently under development, so far only a draft standard called pr EN 45545; has been published [21]. An European research program "TRANSFEU" for updating and finalizing pr EN 45545 started in 2009 and will be finished by 2013 [22].

The objective of measures and requirements in pr EN 45545 is to protect passengers and staff in the event of a fire. Railway vehicle in the meaning of the standard are track guided public passenger land transportation vehicles, for example locomotives, coaches, baggage- and post vans running as part of a passenger train, light rail vehicles, underground vehicles and trams. Freight wagons are not covered by pr EN 45545. In the standard railway vehicles are classified under different operation categories depending on their use as shown in Appendix Table 4 [21].

All vehicles are also classified, as shown in Appendix Table 5 [21], under design categories due to their design. The two categories result in a fire hazard level (HL), which is illustrated in Appendix Table 6 [21], for the railway vehicle in question. The hazard level is the basis for the requirements in pr EN 45545. A high fire hazard level, for example HL4, results in stricter requirements than a low fire hazard level, for example HL1. All new and totally refurbished railway vehicles shall comply with the standard. For partially refurbished vehicles, all new parts and components shall comply with part 2 of pr EN 45545[21].

#### **4- Conclusions and Recommendations**

In the previous chapters an outline for two different types of railway and metro accidents (SPAD due to human error and fire of rolling stock) has been introduced, where discussion and analysis for impacts and causes of accidents have been carried out. Conclusions for the results of that analysis are summarized as follows:

- 1- Though human error proved to be the major cause of many accidents and resultant loss of life, ENR failed to provide improved facilities for the running staff, modernization and up-gradation of training facilities. ENR was also not able to fill all the safety category staff vacancies in the study period
- 2- The period from second half of year 2006 to end of year 2009 is considered the worst for occurring of accidents due to SPADs and due to fire of rolling stocks, whereas 75 % of fatal fire accidents have occurred at the same period.
- 3- Existing train control in ENR and line 1 of Cairo metro uses the track circuit to detect the train position and displays the appropriate signal according to the detected train position. However, this control system requires many trackside facilities and huge investment in construction and maintenance. Also, it is very easy to be repealed on purpose.

- 4- Drivers are responsible for many accidents due to SPADs as in most cases they were unconscious as well as repealing of activity of the ATC devices.
- 5- In year 2010, the rates of accidents were coming down because the drivers have been subjugated to restricted operation orders as well as one hundred trips were cancelled. This action was only taken to minimize the number of accidents regardless any financial considerations for income or its impact on the passenger demand.

Obtained lessons from this study that can be learnt and recommended for reduction of accident occurrence can be introduced in the following points:

- 1- To minimize impact of human error which seriously affecting safety of trains, the design of signaling and driving mode equipment should utilize safe, proven, and reliable components. So the safety and driving mode systems must comply with the following basic principles:
  - To control the routes for the trains, in order they arrive to their scheduled destination.
  - To make sure that each train movement is safe and cannot entail a collision or derailment.
  - To satisfy the performance requirements, that is to say to carry the ridership demand.
- 2- Improve the driver's understanding of the whole operation system. Improve the interface and the operational safety rules/rule book and provide supplementary training to improve the driver's understanding of the relationship between the ATC system and the rest of the signal system and the rule book.
- 3- The recent great progress in IT has now made it possible to build a train control system called "ATACS" (Advanced Train Administration and Communications System) in which each train determines its position and exchanges data with other trains by radio. It is an innovative new train control system that uses IT and autonomous distribution technology.
- 4- Due to the high velocity and very short headways of metro lines, safety of running trains can only be achieved by a combination of appropriate technology including dedicated safety systems, safety management systems, detailed rules and regulations of traffic and trained and qualified staff.

In the field of fire accidents, there are clear opportunities, in addition to the measures which have been mentioned above in item 3.5, to minimize their risk. These can be summarized as follows:

- 1- There is a need for a review of maintenance plans under modern engineering acceptance process.
- 2- Under-frame cleaning regimes should be reviewed to reduce the incidence of dirt and debris – generally impregnated with oil – being ignited by brake block sparks and hot engines.
- 3- Fire detections on the passenger's carriages should be installed.

- 4- Material performance and design of passenger's carriages should be standardized.
- 5- Provision of first –aid fire fighting equipment.
- 6- Automatic fire suppression systems.
- 7- Continued functionality during a fire.
- 8- Driver and staff training and safety management will mainly contribute in reduction of accidents
- 9- Preventing carrying any material with the passengers that can cause any type of fires.
- 10- All safety regulations and standards against fires should be applied strictly.

### **References:**

- 1- ENR, Statistics Reports of Accidents, Jan 2012.
- 2- V.A. Profillidis, Railway engineering, Avebury Technical, England, 1995.
- 3- U.S. Department of Transportation, Research and Innovative Technology Administration, ([http://www.bts.gov/publications/national\\_transportation\\_statistics/html/table\\_02\\_03.html](http://www.bts.gov/publications/national_transportation_statistics/html/table_02_03.html)),2012
- 4- E. Donald Sussman, Thomas G. Raslear, Railroad Human Factors, 2007.
- 5- Terje Andreson, Human and Railway Safety, 1999.
- 6- The Safety Unit in MOT, Monthly Report for Rolling Stock Breakdowns, 2011.
- 7- ENR, Statistics Reports for Accidents from 2000 to 2010.
- 8- ENR, Technical Inspection Report, 9/11/2009.
- 9- ECM, Technical Inspection Report for Metro Accident, 2007.
- 10- Egyptian National Railways Statistics Report No. 65, 10/6/2006.
- 11- Martine Shipp, Centre for fire safety in Transport, Vehicle Fires and Fire safety in Tunnels, BRE, UK, 2001.
- 12- K. Fridolf, D. Nilsson and H. Frantzich, Fire Evacuation in Underground transportation systems, 2011.
- 13- ENR, Statistics Report issued in 2011.
- 14- Office of the Attorney General, Technical Inspection Report, 2002.
- 15- ENR, Official Technical Inspection Report, 2007.
- 16- ENR, Official Technical Inspection Report, 2009.
- 17- Greater Cairo Metro Design Guidelines and Criteria, 1990.
- 18- Terje Andersen, Borre Johan Paaske, Fire Safety in Tunnels and Selection of Tunnel Concept, 2001. (<http://wenku.baidu.com/view/407e0318a8114431b90dd870.html>).
- 19- Cairo University, Faculty of Engineering, Centre of Researches and Civil Engineering Studies, Guidelines of Safety and Service Quality Measures for Transportation by Railways, September 2004.
- 20- British Standard Code of Practice for Fire Precautions in the Design and Construction of Railway Passenger Carrying Trains, BS 6853, 1999.
- 21- European Standard, pr EN 45545, Railway Application – Fire Protection on Railway Vehicles, 2002.
- 22- D. Tooley, A comparison of New European Fire Standards with UK Standards and the Impact on UK Vehicle Design, SAGE publication, 21 Jun 2011.

## Appendix

Table 4: Design categories according to pr EN 45545 [21].

Design category	Description
A	Automatic vehicles having no emergency trained staff on board
D	Double decked vehicles
S	Sleeping and couchette cars
N	All other vehicles

Table 5: Operation categories according to pr EN 45545 [21].

Operation category	Services	Infrastructure	Evacuation
1	Mainline, regional, urban and suburban	Operation not determined by underground sections , tunnels and\or elevated structures	<u>The vehicle shall stop with minimum delay. As soon as the emergency system is activated in the case of a fire onboard.</u> Allowing subsequent immediate evacuation from the vehicles to a place where persons are not affected by fire or fire effluents.
2	Urban and suburban	Operation determined by underground sections, tunnels and\or elevated structures with walk ways or other means for safe side evacuation from the vehicles.	<u>In case of fire alarm, the train will continue to the next station or other suitable stopping points</u> allowing subsequent evacuation from the vehicles to a place where persons arenot affected by fire or fire effluents. Only if this cannot be achieved, then the train in underground sections, tunnels and\or on elevated structures will be evacuated using walk ways or other means for safe side evacuation from the vehicles.
3	Mainline and regional	Operation determined by underground sections, tunnels and\or elevated structures without any means for safe side evacuation from the vehicles.	In case of fire alarm ,the train will continue to suitable ground level stopping point or specially equipped rescue stations allowing subsequent evacuation from the vehicles. Only if this cannot be achieved, then the train in underground sections, tunnels and\or on elevated

			structures will be evacuated using walk ways or other means for safe side evacuation from the vehicles.
4	Mainline, regional, urban and suburban	Operation determined by underground sections, tunnels and/or elevated structures with walkways or other means for safe side evacuation from the vehicles.	In case of fire alarm and halt in these locations, evacuation is extremely difficult, e.g. due to the absence of side walkways.

Table 6: The fire hazard level according to pr EN 45545 [21].

Fire hazard level				
Operation category	Design category			
	N	A	D	S and/or DS
1	HL1	HL2	HL2	HL2
2	HL2	HL4	HL3	N/A
3	HL3	HL4	HL4	HL4
4	HL4	HL4	HL4	HL4