Escalator Accidents Analysis

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Keywords: escalator, accidents, fall, entrapment, safety.

Abstract. More and more; escalators are being widely used to access locations at different levels. The user assumes that the escalators are completely safe but the harsh reality is that accidents happen and in some cases the consequences are fatal.

In order to try to prevent accidents, the first step is to find out why or under what circumstances they occur.

Different committees and organizations around the world collect data about accidents. Existing reports show that since the 1990's a steady increase in the number of accidents regarding escalators have occurred but few statistics on escalator-related accidents have been published worldwide. From the analysis of these statistics, it seems that the assessment of the accidents does not always follows the same criteria as the data is not consistent when reports are crosschecked.

This paper looks at the available records on accidents on escalators, opportunities that currently exist to gather information and parameters analysed from such information.

Also, the paper proposes a systematic approach to escalator accident records to allow that the data gathered provides relevant information that could be taken as a reference for establishing the necessary measures that guarantee the safety of users and escalator technicians.

1 INTRODUCTION

Escalators and moving walks are becoming more prevalent, more complex (longer, higher) and with increasingly exposed voids. In addition, escalators are more and more subjected to abuse, misuse and negligence and in some cases they are the primary escape route/emergency exit. The need for safer escalator designs has been recognized by those who work with escalator manufacturers and purchasers.

1.1 Why do accidents happen?

There are three variables that influence accidents on escalators [1]:

1) *Escalator design***:** electrical and mechanical design of the escalator.
2) *Escalator maintenance, inspection and operation***:**
   - Maintenance refers to activities such as programmed periodic preventive maintenance and/or cleaning.
   - Inspection of all safety devices and escalator components is necessary to ensure the escalator is maintained in a safe condition
   - Operation covers decisions such as keeping an escalator in service, withdrawing it from service or running it as a fixed staircase.

3) *Passenger behavior:* the way in which a passenger behaves has a significant contribution to accidents.

But one additional factor has influence in accidents: the escalator environment has also an important role. Sometimes, accidents involving escalators occur due to some special features around it. For instance:

- Incorrect design of people flow (e.g: ticketing machines too close to escalator landings in metro stations).
- Improper architectural design of the building / installation (locations where a potential situation of risk exists, e.g: open atriums, limited headroom above…).
- Poor lighting and other environmental conditions.

Every accident can be attributed to one or a combination of more than one of these factors. Design issues, as well as maintenance and operation, should be covered by the safety codes and standards. Merely considering escalator design is insufficient to address passenger accidents. Therefore, a diagram of factors affecting passenger accidents on escalators should include the environment as a factor that, once again, never triggers an accident alone; it is always combined with at least one of the other factors. This influence is represented in Figure 1.

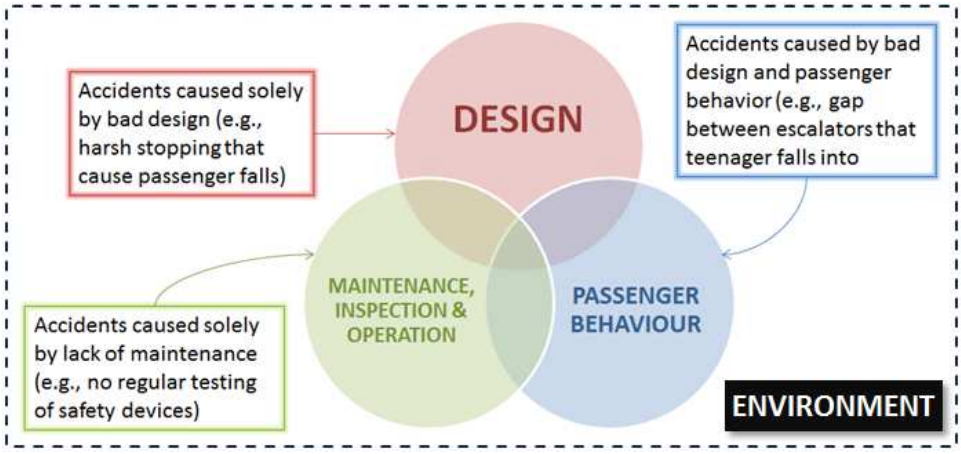

Figure 1 Areas affecting passenger's accidents on escalators [1], adding the environmental factor

1.2 The importance of accident statistics

Accidents on escalators are, in some cases, well documented in terms of the number of accidents occurring but this is not always the case. With respect to the details about how the accident actually occurred and the factors involved they are often not well documented. User accidents are difficult to record because sometimes minor accidents are not reported, escalator companies and owners are not always involved and the way of reporting the main cause of the accident is not properly indicated.

Accident statistics are important to help promote quality, safety and the highest technical standards and encouraging technical progress in the field of manufacturing, installation and maintenance of lifts and escalators [2]. The accident statistics help to:

- identify the causes for accidents, both for users and workers
- analyze hot spots and take actions, e.g. provide new safety norm proposals and influence local government for coming up with new guides or regulations
- use identified regularly occurring accidents by elevator companies to improve their product safety
- support the elevator industry and associations to build up awareness for operators and users

- convince authorities of the actions to be undertaken initially and to confirm the effectiveness of these measures thereafter.

2 ACCIDENT INVESTIGATION

2.1 Methodology

Limited information regarding accidents on escalators can be found as there is no single body worldwide that gathers data on incidents on escalators. In addition, escalator owners and manufacturers are usually reluctant to give this information.

For this analysis, data has been collected from several sources:

- General articles dealing with escalator safety
- Reports from independent organizations that involve industry, owners and third party inspection bodies
- Reports from major clients
- Thesis and dissertations from relevant experts on escalators
- In-house feedback from field experts
- Videos of incidents and media reports

The aim of the analysis was to collect the best accident data and knowledge of the available information. Each of the reports has its special characteristics, all of them valid to the purpose of this investigation:

- Different locations: metro stations, airports, shopping centers …
- Different countries: Spain, Germany, UK, Canada, USA, China ...
- Different goals: point out existing risks on escalators, reduce risks by reaching a new standard, show potential new risks, show patterns on how accidents occur…

2.2 Accident analysis

The analysis tries to answer as best as possible the questions of how many accidents are occurring and how and where they occur from the prospective of real data. The conclusions of the analysis have been detached in three different areas: the quality of the reviewed data, the analysis of the main causes of accidents and their statistics and finally the peculiarities of fall accidents.

1) Accident data

- Criteria to report accidents are not clear. As accident reports come from very different sources with very different purposes it is almost impossible to compare the results among them and extract similar conclusions. In addition, there is no single body worldwide that gathers all the accident-related data.
- Data is not consistent: some independent investigations made by escalator operators in Europe [3] show a higher number of reported accidents than the official ones reported by ELA [4] for the same year, where data is provided by the key manufacturers. This is probably because manufacturers are reluctant to show accidents involving their equipment.
- Significant associations between major accident causes and other contributing factors could help to reconstruct the accident scenarios and develop prevention measures. For this purpose it is necessary to construct a proper template of accident reporting that can register all of these elements involved in the accident.

2) Main causes of accidents

- Although there is a “belief” that the most critical part of the escalator is the step gap and many efforts have been made by different manufacturers to reduce/avoid this gap, all the statistics and information consulted show clearly that the main accident cause in escalators is

falls (42-88% depending on the source). This is not only regarding the number of accidents but also because they often cause more severe injuries and more fatalities.

- Alternatively, *entrapment* is mostly associated with the age of the escalator and its code compliance level or maintenance status (a much stricter requirement for EN115 adopted in MTR decreased the occurrence of this type of accident to 5.7% of total accidents [5]).
- Statistics show that there are some risk groups depending on age and gender [5]:
    - Young males under 5 years are more likely to suffer entrapments.
    - Children between 5-15 years tend to fall over the escalator due to being unsupervised by an adult.
    - Accidents happening to adults from 15-65 involve rushing, carrying other tasks, playing on escalators and other kinds of misuse.
    - Elderly people (>65 years), especially women, tend more to lose balance and fall.
- There are many serious risks associated with the use of carts and trolleys on escalators and moving walks [6].The risks include overloading, carriage of children, runaway and other foreseeable misuse.

3) Falls

- "Slipping on landings/steps/pallets" makes up the majority of the escalator accidents.
- "Falls over the handrails" are often tied to misuse, such as jumping from one level to another, or attempting to ride by sitting on the handrail, usually in a state of intoxication. [7].
- Another type of fall is "falling from escalators". These mainly take place whenever the escalator is located in a void (as is the case in most shopping centers). Due to the height of the fall, the injuries are usually very severe (death in some cases) [7].
- One of the most important items in reducing the probability of passengers falling is ensuring that the escalator stops in a smooth manner.
- Another extreme accident that could take place on an escalator is a passenger falling 'into' the escalator step band due to a missing step or a step collapse. These accidents are rare but have drastic consequences when they take place.

3 METHODOLOGY PROPOSAL

3.1 First approach: ELA statistics

The European Lift Association (ELA) represents the lift, escalators and moving walk associations active in the European Union (EU) and also represents their component manufacturers. One of the main goals of this organization is to promote quality, safety and the highest technical standards in the elevation field.

More precisely, the ELA Statistical Committee aims to collect regular data and updated information to set up databases and to publish statistics related to lifts, escalators and moving walks. Since 2008 this committee has been collecting data of accidents by asking its partners to report the accidents that occur on lifts and escalators. The collection covered 30 countries and it is divided into the following categories:

- Workers accidents:
    1. Classification: installation, service
    2. Accident causes (e.g. "unsafe access to machine room")
    3. Severity: fatal, serious, minor
- Users accidents:
    1. Causes: technical reasons, human reasons
    2. Severity: fatal, serious (different definition for serious than for workers), others
- Additional "Fatal accident report"

Accident statistics have been collected since then but the results were not satisfactory due to: too few participants, too many discrepancies and "strange" results when comparing different countries, difficulties in classifying accidents following the risk list, etc. In addition, the number of accidents collected for a whole country is very low in comparison with data provided by single clients and incidents are not being registered.

Methodology for collecting this data consists of sending a simplified form to each association in order to have comparable figures and receiving it back filled in with the corresponding data. This simplified form is provided by ELA since most European countries have their own system of collection based on different aspects of the accident (associated risk, injury/part of the body hurt…). This report is anonymous and not linked to individual companies as there are many companies reluctant to communicate their accidents/incidents figures. The aim is to get the best knowledge of accidents possible.

From the first years of collection the reporting has also changed due to the fact that few countries have participated in the past and also the previously mentioned discrepancies in the figures. The last reporting method focuses on the main causes of accidents identified in the SNEE brochure (Safety Norm for Existing Escalators) which is also published by ELA.

However this methodology only helps to link the number of escalator accidents with the causes or the severity of each accident, ignoring important information about other facts that have proven to have influence over the occurrence of the accident such as passenger conditions (age, intoxication state…) and, more importantly, escalator characteristics (installation year, code requirements, rise, speed, location, …) which would help to prevent accidents and mitigate their consequences significantly in the future.

3.2 Client-orientated accident reporting

There are three main figures linked to an escalator in use. *Manufacturers* are responsible for the design and installation of the escalators, but the *client*, as owner of the equipment, is usually responsible for any issue caused by this equipment. *Maintainers*, hired by the client, are in charge of the operations needed to keep the escalator in proper operation, and sometimes it is usual for them not to be the same as the manufacturer.

With this in mind it is clear that the clients are the most concerned about the escalator performance so it seems reasonable that the best knowledge of the equipment is held by them as operators. In addition, some clients have more recently been monitoring their escalators. Many of them own devices that help to manage supervision of the machines, such as real-time view of the equipment status, centralized controls, traffic history playbacks, security cameras, tracking of safety devices etc…The information recorded by these devices would help to gather data about not only accidents but also incidents because, in the same way, they are a sign of an unsolved and/or unsafe situation.

For the reasons above a methodology is suggested for collecting data involving some key-clients that can provide their data and experiences.

Among the findings of the accident investigation, it was concluded that the typology of accidents also differs depending on the type of escalator installation (e.g. accident type "fall from escalators" occurs more often in places where escalators lead to a void such as shopping centers). For this reason key-clients could be classified in the same categories as the *escalator duty* which is defined by three functions: application, location and capacity (persons per hour). Then, the classification will be as follows:

- *Heavy duty:* convention centers, stadiums and airports where there is a very high traffic volume. These applications could be indoors or outdoors and designed for higher rise applications up to about 50 m.

- *Transit:* railway stations, airports and subway stations where there is a very high traffic volume. These applications could be indoors or outdoors and designed for higher rise applications (about 20 m).
- *Commercial:* department stores, shopping malls and office buildings. Most of these applications are indoors but can be installed outdoors. The maximum rise of these applications is about 9 m.

Regarding data recording, only reporting the number of accidents and their consequences has been proven to be inefficient. Relevant information that could help to clarify the accident circumstances is not normally registered. A proper accident report template should cover relevant factors plus escalator information, as well as any other factors which are judged to be relevant:

- *General information:* major cause (listed under defined categories), site and time of the accident, weather conditions, witness information (including the victim where possible)…
- *Passenger data:* age and gender of the victims, number of involved people, injured body part, severity of the injuries, position of passenger at time of incident, state of intoxication, unaccompanied children, clothing type and condition, task factors …
- *Escalator features:* year of manufactured, code compliance status, rise, speed, traveling direction, indoor or outdoor location, location of emergency stops, location of the incident (top landing, lower landing, mid part, external to the escalator…) safety signage, safety devices, technical analysis of the escalator after inspection by the maintenance staff…

The statistical treatment of this data will help to establish associations between the major causes and the contributing factors by extracting more precise information to reconstruct the accident scenarios and develop prevention measures for minimizing number of accidents on escalators and their consequences.

4 CASE STUDY: TRANSPORTS METROPOLITANS DE BARCELONA

The Metropolitan Region of Barcelona (MRB) includes a total area of 636 km^2 and a population of over three million. The demand for collective public transport in the Barcelona area was 899.6 million journeys in 2012. Of this total number of journeys, over 550 million (61.5%) were made on TMB (Transports Metropolitans de Barcelona) and 373,5 million in Metro. To ensure the accessibility at all links of the transport network, a number of lifts and escalators are installed on stations and access points. The overview of escalators installed can be seen in Figure 2.

Total number: 602	
Escalators	Moving Walks
582	20

	Escalators	Moving Walks
Ascending	82,5%	40,0%
Descending	13,3%	40,0%
Reversible	4,2%	0,0%
Horizontal	0,0%	20,0%

Length	Average	5,25 m.
	Longest	16,4 m.
	Shortest	1,3 m.
Speed	0,5 /0,65	m/s

Figure 2 Overview of TMB escalators

TMB presented at the 2014 ELA Conference the plan to upgrade the old units to EN115-1 following EN115-2 in the next 4 years based on their own accident statistics collected from 2010 to 2013. The need for this update responds to the high rate of accidents per year on the older units. The plan consists of the assignation of individual priority to each escalator depending on the

classification of hazards from the standard, the number of passengers, history of accidents and organizing different adaptations required to minimize the number of interventions in each machine.

4.1 Managing information about accidents involving escalators

The computer-aided maintenance software used in the Barcelona Metro provides, for each piece of equipment on the Metro network, a technical object within the data fields to characterize each facility with all of the information necessary to carry out maintenance and is also useful for further analysis of data.

Regarding escalators; general data includes the manufacturer, model, year of manufacture, date of commissioning, standard compliance, height, tilt speed, step width, number of steps, direction of travel, number of flat steps at landings, indoor or outdoor location. There are also others with more technical information such as the type of drive chain, motor power, if it has a drain in workers area, if there's lighting under handrails and what kind, handrail lengths, etc. which are used to help the technical staff to carry out the repairs.

The same software is used to manage the corrective and preventive maintenance and any maintenance undertaken is registered in the maintenance software. Breakdowns are registered in the computer-aided maintenance software and also every incident that may occur in the metro network including accidents on escalators.

When a breakdown or other incident occurs the operator has to create a notification by using the software. In the resultant documentation produced all the information about the incident is registered: *when* (date & time), *where* (in what technical facility it occurred) and *what* happened (element, symptom, cause). These data fields have catalogs of standard codes. Some of them are filled in by the operator and others by the maintenance staff giving extra information after the inspection of the escalator. In the event of an accident the "symptom" field is used to encode the accident type e.g. fall without cause, slipping on steps/pallets/belt/and on landings, entrapment between comb and step/pallet, etc.

This allows all accident data to be linked with each one of the Metro escalators and by extracting the data it is possible to calculate the ratios of accidents and their type for each escalator or for any of the characteristics of the escalators.

4.2 Safety in escalators: Barcelona Metro Experience

Figure 3 shows the main accident statistics regarding escalators extracted from the TMB maintenance software between 2010 and 2014. The typology is based on what happened to the users or the consequences to them. The most remarkable data is that *falls* are the main consequences of accidents on escalators, being the result of 88.9% of the total number of accidents (including all types: fallings without cause, slips, massive falls, handrail speed deviations, backward motion…). Another interesting piece of data is that only 7.5% of the accidents are the result of *entrapment* (between combs and step pallets, between skirting and steps or at handrail entry).

Accident	2010	2011	2012	2013	2014	Total	
Fall without cause	202	163	120	217	200	902	48,0%
Slipping on steps/pallets/belt/and on landings	112	159	159	162	141	733	39,0%
Entrapment between comb and step/pallet	22	20	21	20	18	101	5,4%
Cuts or injuries to hands, arms..	13	12	20	4	18	67	3,6%
Trapping between skirting and steps	7	17	5		7	36	1,9%
Massive fall without cause	1	6	5	6	5	23	1,2%
Falling due to hand rail speed desviation (or stop)	2	2	3	2	1	10	0,5%
Trapping at handrail entry			2	1	1	4	0,2%
Fall due to backward motion	1			1	1	3	0,2%
Total	360	379	335	413	392	1.879	100,0%
					Average per year	375,8	

Figure 3 Accident statistics on TMB escalators 2010 - 2014

In addition to this general data, TMB has quantified other interesting facts, for instance, the average accidents per year and per escalator related to the escalators' age. This can be seen on Figure 4 where it is easily noticeable that there is a high dependency on the ratio of accidents per year per escalator and its age, more or less doubling the ratio of accidents with each decade of age.

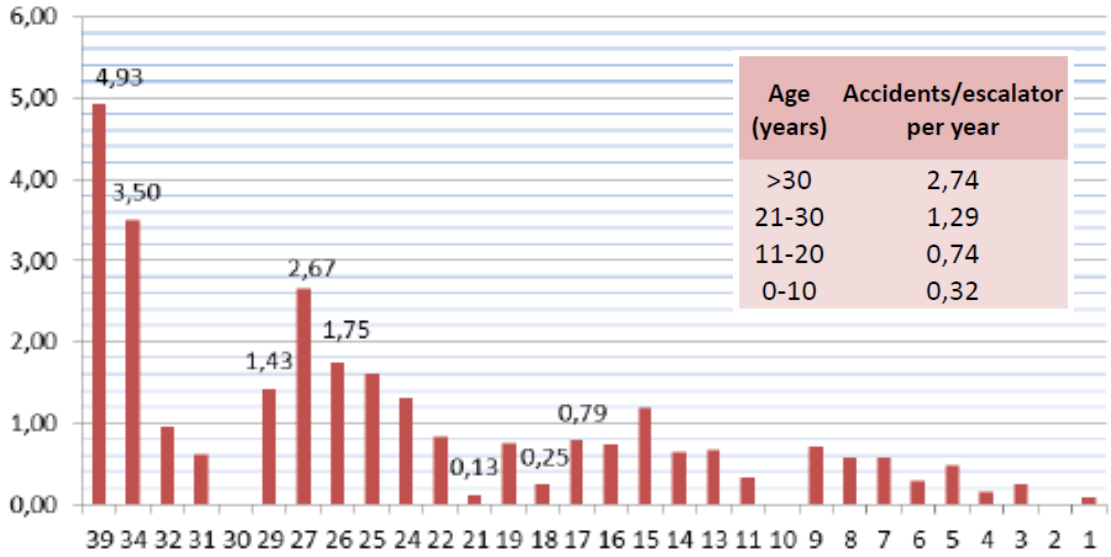

Figure 4 Average accidents per year and escalator compared to the age of the escalator (years). Updated at 31.12.13

Another example is the comparison between the location of the escalator, the climatic conditions and the running directions. It could be thought that outdoor escalators could have a higher ratio of accidents than indoor escalators (because of wet shoes after rain) or indoor descending escalators could have more accidents than ascending escalators (because people could be on a hurry in indoor descending escalators when they see the train at the station) but the truth is that the location of escalators with higher rates of accidents are indoor ascending escalators (0,777 accidents per year/escalator). The cause for this could be that passengers frequently walk up the escalators.

Location	% Escalators	% Accidents
Indoor	77,98%	85,30%
Outdoor	22,02%	14,70%

Number of accidents per year/escalator		
Indoor	0,773	210 % More accidents indoor escalators
outdoor	0,368	
Descending	0,576	19,7 % More accidents ascending escalators
Ascending	0,689	

	Descending	Ascending
Indoor	0,750	0,777
outdoor	0,319	0,388

Figure 5 Accident rate versus location and running direction. Updated at 31.12.13

These are only a few examples of what proper data collection and interpretation could tell us about accidents involving escalators. In this case statistics help to justify an investment on upgrading the safety level for older escalators which will lead at the end of the process to an expected 75% reduction in the number of accidents along the network, supposing that the upgraded escalators reach the same accident ratio as the escalators complying with EN115-1. Even only reaching half of the current ratio of accidents would be expected to reduce the number of accidents by 50%.

5 CONCLUSIONS

There is a real need to collect reliable escalator accident data which could help to identify potentially dangerous situations that can be sources of risk for users or technicians on escalators. Accident investigation is a preventive action whose starting point is, in contradiction, the prior existence of an accident. Its importance is in the objectivity of the data: an accident indicates the actual existence of a hazard and therefore a risk. The registration of these cases, and also incidents, and their statistical treatment provides evidence of how, where, when and how many accidents are occurring. After analyzing this data it is possible to throw light on why they occur.

Research made on the topic “accidents on escalators” showed that there is no common criterion to record accidents, thus data obtained is not consistent. Reports come from different sources with very diverse goals which also makes it very difficult to establish a base for comparison. In addition, the majority of the reports are focused on the consequences of accidents and passenger data, forgetting about escalators characteristics, which in many cases have a big impact in accidents.

The European Lift Association (ELA) has been collecting accident data from its partners since 2008 using a common template but the main data is provided usually by manufacturers, who are sometimes reluctant to declare accidents on their machines, so there are many inconsistencies between the data. When data from ELA reports is cross-checked with data from different sources, it seems that reliability of the data could be doubtful.

Client-orientated methodologies for collecting information about accidents and incidents on escalators (including machine features), plus clear definition of objective data and appropriate treatment of the figures, will improve the quality of the information obtained to extract the most

precise information possible. The experience of Metro Barcelona shows how proper templates, data registration and statistical analysis can help to improve safety and reduce the number of accidents and their consequences on escalators to a large extent.

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ACKNOWLEDGEMENTS

The main authors wish to express their most sincere gratitude to Ignasi Oliver and TMB for his unconditional involvement and support during this research process.

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