Summary

Escalators belong to the group of vertical transportation equipment and are a continuous means of transport. Nowadays escalators can be encountered in public places like metro or train stations, airports and shopping malls. Together with elevators, escalators changed the way in which people are transported as they both facilitate the human's vertical conveyance.
The very first escalator-like patent was granted in 1859 to Nathan Ames. The following similar patent was granted to Jesse W. Reno in 1892 and was produced in 1896. His escalator was a cleated inclined moving belt with handrail. Also in 1892 the escalator design of George A. Wheeler was patented. His escalator was a real revolving stairway. Wheeler's patent was bought by Charles D. Seeberger in 1899. Seeberger further developed and produced this patent together with Elisha Otis. Both the escalators from Reno as well as from Otis/Seeberger were shown at the 1900 World exposition in Paris. At this exposition the apparatus also got the name Escalator (with capital E and trademarked) which was thought up by Seeberger. Until about 1920 the available escalator designs were either the Reno or the Otis/Seeberger type. The Otis design was a cleated inclined belt with moving handrail and comb plates. The Otis Seeberger type was a moving stairway with flat steps and a moving handrail. The steps were driven by a chain from underneath. In 1921 the Otis Elevator Company reengineered the escalator by taking the best of the previously described types. This resulted in the escalator with features as we know it today. Today's major escalator producers – like for example KONE, Schindler and ThyssenKrupp – emerged in the following years. In the years until now a lot of special escalators were designed like the spiral escalators, cart conveyors and the escalator's brother the moving walk.
The modern escalator is build up as follows: The main support structure for an escalator is the truss which is the box like lattice structure below the steps. At the top and bottom landing platforms are situated. Attached to these landing plates are comb plates which mesh with the cleats on the steps. This minimizes the gap between the steps and the landing platforms to reduce the chance of getting caught between them. The cast aluminium steps have a cleated step surface and cleated riser (vertical part of the step) for the same reason. The steps are pulled by a pair of step chains which are attached to either side of the steps. The steps are supported by four wheels which ride in four tracks, two on each side of the escalator. The relative position of the tracks to each other is what makes the steps flatten at both ends of the escalator and makes them stair-like in between. On both sides of the steps are the balustrades over which the handrails move. The moving handrails move at the same speed as the steps to provide passengers a place to hold on for their balance.
The escalator is driven by an electric motor attached to a gearbox. This gearbox in turn drives the step chain drive sprocket by a drive chain. The AC induction motor is controlled by a Variable Voltage Variable Frequency (VVVF) drive. The escalator contains an operational and an auxiliary brake. The first one is an electro mechanical brake while the other is a mechanical friction brake. The handrail can be driven directly from the step chain drive or have a separate drive.
When an escalator will be used in a building the civil construction has to be adapted to accept the truss. At both ends the escalator's truss support points have to be specially reinforced to support the escalator's weight. At the bottom landing a pit has to be prepared to accept part of the truss and at

the top landing electrical connections have to be prepared. The placement of these support points is dependent on rise and inclination of the escalator. The type of escalator has to be selected by keeping factors like passenger flow, available space and indoor/outdoor placement in mind. When multiple escalators are installed in the same building/space, there are a number of combinations possible like crisscross and parallel arrangement.

Escalators are produced in inclination angles of 27,3° to 35°. Speeds vary between 0,5 m/s and 0,75 m/s. Steps come in the widths of 600, 800 and 1000 mm. Maximal effective transport capacity of the largest escalators is about 7300 persons/hr.

When riding an escalator there are various dangers and hazardous areas. They range from gaps between moving parts to fire and abrupt stops. Part of these dangers are mechanical failures/hazards, however a large part is created by faults of the passenger itself. Solutions have been developed for most of the dangers/hazardous areas on escalators to limit or reduce the impact of incidents (like for example skirt brushes, anti-friction coatings and comb plates). Also many of the dangerous areas are guarded nowadays by sensors which are connected to a central PLC. Examples are the broken step chain device, handrail safety switch and broken step device. When a failure is detected by one of these devices a signal is sent to the PLC which in turn activates the brake to stop the escalator.

Every country uses its own set of standards, which contains rules and regulations about the minimum safety level a new escalator has to achieve. There are two standards which have been adopted by many countries especially within Europe and North America, namely the EN 115 and the ASME A17, respectively. The ASME code has a special section, named ASME A17.7 Performance Based Safety Code for Escalators and Elevators. This code enhances free trade on a market (in this case the US and Canadian market) as the minimum safety requirements are mandatory for each installation but deviations in aspect, technology used and performance of non-safety related component are accepted.

First inspection and certification is not mandatory in every country, but it is recommended to reduce liability of the escalator's owner in case of an accident. Notified Bodies are appointed for these first inspections. Maintenance is not mandatory but it is preferred by the escalator's owner for improved reliability and increased lifetime of the expensive escalator.

The human is the most important factor in escalator safety. Many of the accidents can be prevented with the correct behaviour when entering, riding and exiting an escalator. Learning programs and campaigns have been set up to improve this awareness.

When an escalator needs replacing, there is also the option of modernization whereby everything but the truss is replaced. The new parts are mounted in the old truss, thus saving much work and especially money by not having to remove the old truss but still having all the advantages of a new escalator.

With the concerns about the environment, escalators now also have many options to reduce their energy consumption. A few examples are the VVVF motor drives, the sleep mode when nobody is using the escalator and LED lighting.

Not much research is done in the direction of escalators. There are however a few interesting developments in the escalator world. Condition based maintenance and condition monitoring are used to improve maintenance quality and timing. Remote monitoring is used to remotely check, monitor and control escalators. There are interesting developments in the spiral and free curving escalators with the Helixator and the Levytator.

Concluding this it can be said that the current world would struggle in crowded and elevated/lowered places like airports, metro and train stations if escalators would not have been invented. They play an important role in public transport, as they retain the mobility fluent by providing continuous vertical transport. Environment and safety are two "hot topics" in the escalator world. To progress in these topics the industry will have to look into the details of the escalator because the largest profits have already been achieved, i.e. most components have already been optimised.

Recommendations for further research are in the direction of energy consumption and safety. Firstly, it could be interesting to search whether there any areas/parts in an escalator may have been overlooked where potential energy savings are possible (like for example the sliding handrail). A study of the possible solutions could be done. Secondly, the industry has developed various additions to improve safety (such as skirt combs). A study could be done to see whether it is possible to look at a more basic level to improve safety (changing existing parts instead of adding new parts).