RISK MITIGATION ASSOCIATED WITH AIRPORT ESCALATOR AND MOVING SIDEWALK OPERATIONS

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Executive Summary

Escalators and moving sidewalks are effective in their function, but periodically injure their users. This paper will discuss the types of injuries that occur on escalators and moving sidewalks and proven methods to mitigate the risks and minimize the potential for injuries in airports. Strategies to minimize an airport’s exposure to litigation following an escalator or moving sidewalk injury will also be discussed.

An airport's escalator and moving sidewalk safety program should focus on reducing the most common injuries in the higher risk age groups. Young children and older adults are most commonly injured. Falls are common in both age groups, but children are also most commonly entrapped by the escalator mechanism. Preventive measures provide better outcomes when focused on preventing these types of escalator injuries. Some escalator safety features can only be included during the initial installation, but many other cost effective safety retrofits can be added, subsequent to the initial installation. The positive results of these safety features have been researched and tested in mass transit hubs, such as subway stations, and these findings can be applied to airports.

Even with all these well intended precautions, incidents still occur. Since the cause of many escalator and moving sidewalk incidents is human error, a comprehensive incident investigation program aids in minimizing an airport’s exposure to liability. This will ultimately help to highlight the importance of incorporating safety features to a new or existing escalator or moving sidewalks in an airport.
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**Abbreviations**

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<th>Description</th>
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<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>CSA</td>
<td>Canadian Standards Association</td>
</tr>
<tr>
<td>MTH</td>
<td>Mass Transit Hub</td>
</tr>
<tr>
<td>TSSA</td>
<td>Technical Standards and Safety Authority (Ontario)</td>
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1.0 – Introduction

As an airport terminal grows to more than one storey, escalators and moving sidewalks become critical in maintaining the efficient movement of airport users. Escalators and moving sidewalks are effective in their function, but unfortunately periodically contribute to injuries. This paper will discuss the types of injuries that occur on escalators and moving sidewalks and proven methods to mitigate the risks and minimize the potential for these injuries. Furthermore, when an escalator or moving sidewalk injury occurs, strategies to minimize the airport’s exposure to litigation will be discussed.

Practical solutions to help airport operators eliminate or reduce the occurrence and severity of injuries on escalators will be highlighted. There will be a review of the common types of injuries on escalators and the populations at highest risk of escalator injuries. Possible solutions for these injuries will be reviewed. Some solutions can only be included during an escalator installation. Many other solutions are simple and cost effective safety upgrades to existing escalators. Ultimately, the proposed solutions will help to reduce the impact of escalator related injuries and subsequently reduce the possibility of litigation associated with these injuries.

Even with the proposed preventive measures, escalator injuries still occur, so the importance of reducing the airport’s exposure to litigation will be reviewed. Airport operators will gain valuable information to justify improvements to their escalator and moving sidewalk safety programs. An airport operator has both a financial and moral obligation to find solutions to eliminate and/or reduce the incident and severity of escalator injuries to as low as reasonably practicable (ALARP).
1.1 – Escalators and Moving Sidewalks in Airport Design

Airports are ideally suited for escalators and moving sidewalks because of an airport’s form and function. Escalators provide the most efficient method of moving a large number of passengers between adjacent floors\(^1\). Since the vast majority of passengers navigating airport terminals will use only two or three floors of the terminal, the escalator is a more efficient option than an elevator\(^2\). By comparison, elevators are more effective moving people in tall office towers with small footprints. Escalators, unlike elevators, are always available to their users, resulting in little to no escalator wait times\(^3\). In the event of an escalator breakdown, the escalator can at least function as “stairs”, whereas elevators do not offer this option. Escalators also have a much greater passenger capacity than elevators\(^3\). These features help to establish escalators as the preferred option for airports.

As an airport terminal grows to more than two stories, escalators continue to be the ideal passenger conveyance between the arrival and departure levels. Other floors are typically used for administrative or supportive functions, so most airport users navigate only the arrival and departure levels via escalators.

Escalators have many advantages over elevators in an airport terminal, but injuries associated with escalators, although statistically rare per use, are many times more common than on elevators\(^3\). Although, the escalator injury occurrence rate per use is low, a high rider frequency predicts that one or more escalator injuries may occur every month within larger Canadian airports.

Long concourses or lengthy distances between connecting flights increase the demand for moving sidewalks. Moving sidewalks help to move passengers long
distances without stopping. For example, a moving sidewalk is desirable in an airport terminal to travel long distances between connecting flights, but is not suitable in an airport’s shopping centre, where moving sidewalks discourage stopping and shopping. Moving sidewalks are highly efficient in helping people cover a certain distance quickly with minimal physical exertion. Airports are uniquely suited to moving sidewalks because of an airport’s large footprint. In fact, airports are home to a vast majority of the world’s moving sidewalks. Moving sidewalks and escalators have different functions, but most of the safety solutions highlighted can be applied to either mode of transportation.

1.2 – Comparison of Risk and Function of Escalators and Elevators

Escalators provide a common mode of personal transport in airports and other settings. There are approximately 33,000 escalators and moving sidewalks in the United States compared to 630,000 elevators in the United States. Even though there are a greater number of elevators, people use escalators more often than elevators. Americans take 180 million escalator rides every day compared to only 55 million rides on the more plentiful elevators. Escalators are the choice for people who want rapid movement between a few floors of a building. Accidents occur more commonly on escalators than elevators with 16,000 accidents per year on escalators compared to only 2,000 on elevators. Even after correcting for the number of rides per year, escalators continue to have a greater accident/incident rate than elevators.

Ironically, one safety feature imperative for every escalator is an elevator. For those users who are unable to properly use an escalator, an elevator becomes the safer, although less time efficient, option. Generally, research shows that people in
wheelchairs or similar devices such as young children, the elderly, people with baby strollers or carts, or people with luggage are at an elevated injury risk using escalators. These individuals should be directed and encouraged to use an elevator. Every escalator should have an elevator in close proximity that is easy to locate and can be accessed from either end of the escalator. If the elevator is difficult to find, or is too far away, then people will opt to use the escalator because of the lack of an apparent elevator option. When installing an escalator in an airport, ensure that an elevator option is in close proximity. Airports with pre-existing escalators should ensure that an elevator option is obvious to airport users. If an elevator option is not obvious, the way finding to the elevators must be improved to ensure the elevator option is well delineated at each end of the escalator.

In order to discourage higher risk escalator users, the airport elevators should be large enough to accommodate carts, strollers, wheelchairs, and luggage. Luggage carts, strollers and shopping carts are especially hazardous on escalators because they are difficult to control and can lose part or all of their entire load. When something falls off a cart, it becomes a hazard to other escalator users, as it tumbles down the escalator.
1.3 – Escalator and Moving Sidewalk Safety Research

There is limited information on maximizing escalator or moving sidewalk safety in an airport terminal. Although, there is little airport specific research on escalators and moving sidewalks, there is sufficient research on Mass Transport Hubs (MTH), such as train stations and subway stations\(^2\). There are several similarities between airport terminals and MTH. Both have multiple users who are accessing or egressing from public mass transportation and the users are frequently rushed. In addition to being rushed, airport users often carry luggage which can make using escalators more hazardous. Unlike MTH, airports have a high proportion of users that rarely use the facility and more users that travel from greater distances. They are often unfamiliar with the facility and are typically distracted and less focused on using the escalator safely than on finding their way through the airport. Although airports and MTH have some differences, they have sufficient similarities so that the lessons learned in MTH escalator safety research can be applied in airports.

1.4 – Escalator Safety Features

Escalator safety is improved through the use of high quality equipment. When installing a new escalator in an airport, ensure that the equipment choice is based on the total cost of ownership and not simply the up-front cost. The purchase cost of an escalator is usually much less than its total lifetime maintenance cost. Quality escalator and moving sidewalk equipment combined with a good maintenance program should allow the equipment to last for thirty years\(^2\). Making purchasing decisions based on the total cost of ownership favors better quality equipment with better safety features. The MTH data suggests that the up front cost of an escalator’s optional safety features is far
more affordable when factored to include the overall cost of ownership. Furthermore, both airports and MTH operate around-the-clock, and there is a requirement for equipment maintenance to be done while the building is open to the public. Higher quality equipment generally has higher quality safety features and tends to be more reliable with less operating downtime. Choosing high quality escalators helps to improve customer service, reduces overall operating costs and reduces the risk to escalator users.

A number of cost effective safety features can be added to existing escalators and moving sidewalks, to minimize the safety hazards in all quality levels of escalators. These safety features have been tested in MTH and other facilities and are designed to actively limit the user’s exposure to known escalator hazards. Safety features added to an existing escalator will be reviewed in Section 3.0.

1.5 – Escalator Parts Review

A technical review helps to provide airport managers with a working knowledge of escalator parts and to better illustrate the safety issues and solutions presented in this paper. The escalator terms are described in Figure 1 and ensure that the information presented is relevant for any airport manager or experienced escalator technician.
2.0 – Injuries on Escalators

Escalators are relatively safe modes of pedestrian transportation. The injury rate of escalator riders is 221 yearly injuries per 1,000 escalators\(^1\). Based on this, an airport with as few as five escalators could statistically expect one notable injury every year,
requiring an emergency services response. By comparison, elevators have an injury rate of just fifteen yearly injuries per 1,000 elevators or fifteen times less risk of injury than escalators\(^1\). To initiate an effective airport escalator safety program, it is important to have an understanding of the most commonly injured age groups in the population and the precipitating causes of injury.

### 2.1 – Escalator Injuries Affecting Young Children and the Elderly

Young children and the elderly are the age groups most commonly injured on escalators. In the United States, there are an estimated 2,000 annual injuries to young children and 73,000 annual injuries to adults, including the elderly\(^5\). Within Canada, the Technical Standards and Safety Authority (TSSA) is responsible for regulating the safety of more than 43,000 elevating devices in Ontario. These elevating devices include elevators, escalators, moving walks, lifts for persons with physical disabilities, passenger ropeways, construction hoists and ski lifts. The TSSA regulates 1,765 of Ontario’s escalators and moving sidewalks\(^4\). A legislated requirement to report incidents makes it a noteworthy source of Canadian escalator safety information. Between 2001 and 2005, the TSSA reported eight serious injuries, five of which involved seniors\(^4\). When all types of injuries are considered, 83% of injuries are caused by human behavior while only 6.7% were caused by defective components\(^4\). Almost half of the injuries involved children under five years old and adults over 65 years old\(^4\). Almost all cases of injuries to adults over 65 years old were a result of falls, while injuries to young children were a result of falls and/or body entrapment\(^6\).
Based on this information, airport programs designed to improve escalator safety will have the greatest impact by targeting young children and adults over 65 and by focusing on human escalator riding behavior. Some of the injuries, such as falls and entrapments are age specific; hence, the solutions should also be age specific. Finally, the relatively low number of injuries caused by defective equipment is based on the high maintenance standards mandated by the TSSA. In contrast, in other reports, 31% of injuries were linked to maintenance issues, like missing parts and sudden stops. This is an endorsement for high standards of escalator maintenance, based on the lower injury rates.

Young children are involved in escalator incidents, because they are learning how to ride them properly or are naturally curious and exploring how they function. An airport’s escalator safety program must take into consideration how young children behave when learning about escalators. Half of the injuries that occur in children under eighteen years old occurred in the two to four year old age group. Young boys and girls are equally involved in escalator related injuries. Interestingly, children between the ages of two and four who were injured were often attempting to ride the escalator correctly. Half the time, other age groups are not holding the hand rail or about one third of the time, they are riding improperly. Interestingly, in 69% of all injury cases, the children are under direct adult supervision. Parents or other caregivers should also realize that escalator and moving sidewalks are mechanical devices and should not be used as a toy. Too many parents take children onto escalators for the “thrill”, without realizing the inherent dangers.
The cause of most childhood escalator injuries is not following the basic safety rules for proper escalator riding. The theory that children who are injured are not being supervised by adults appears false. Both children and adults need to be better trained on the basic safety habits of riding an escalator. When a child is injured, 51% of the time it involves a fall leading to blunt trauma and lacerations\textsuperscript{5,7}. In 29% of cases, the fall led to an entrapment within the escalator mechanism\textsuperscript{3,5}. In two thirds of cases, the entrapment is between the side of the step and the skirt\textsuperscript{3,5}. The remaining cases of entrapment are within the comb plate or between steps\textsuperscript{3,5}. Escalator entrapments predominantly involve the hands of children under five years old and the legs of children over five\textsuperscript{3,5,7}. Strollers are involved in virtually all injuries to infants. The injuries result predominantly through falls from the stroller or to a lesser extent through the loss of control of the stroller\textsuperscript{5}.

Airports, subways and similar mass transit stations represent 81% of the settings of escalator related injuries to children\textsuperscript{7}. By contrast, only 12% of injuries are in stores, 4% in offices and 4% in schools\textsuperscript{7}. When a child is severely injured, resulting in hospitalization, 50% require operative intervention with an average of 13 days spent in the hospital, 46% resulted in cosmetic deformities, and 15% resulted in significant loss of function\textsuperscript{7}. Entrapment causing amputation or avulsion is uncommon, but when it occurs it is most frequently in children under five years old and almost always involves the hand\textsuperscript{6}. An airport escalator safety program should focus on minimizing the severity of injuries to children because airports are better positioned to improve an escalator’s mechanical safeguards than to improve an individual child’s escalator riding skills. Mechanical safeguards that limit a child’s chance of being entrapped in the side of the
step, the comb plates or between steps will significantly reduce the severity of injuries that do occur.

2.2 – Escalator Injuries Affecting Adults

Adults who are involved in escalator accidents tend to be distracted, and are rushed or carrying out other tasks. Older adults are more commonly involved in escalator and moving sidewalk accidents than any other age group. The most thorough study of escalator safety in a mass transit station was on Taipei’s Rapid Transit system. In 2000, there were 194 escalator-related accidents in 238,036,219 trips through the system\(^8\). This gives an accident rate of 0.815 accidents per million passengers through the system\(^8\). The majority, almost 90%, of injuries to the elderly were caused by falls with approximately 6% entrapments and the reminder attributed to other causes (Table 1)\(^8\). A United States study suggested three times the number of entrapments incidents, but falls still remained the highest cause of incidents (Table 1)\(^6\). The difference may be attributed to added safety procedures used in Taipei’s escalators. The contributing injury factors were carrying out other tasks such as: carrying luggage, looking after someone else, loss of balance, not holding handrail, unhealthy or intoxicated passenger, and being struck by another passenger (Table 2)\(^8\). The TSSA reports similar results, but compiles many of the causes together as Human Factors accounting for 91% of injuries\(^4\). The remainder of injuries were a result of operational and other concerns: 1.7 % due to equipment faults, 0.4% due to defective design, 0.2% due to weather and 2.2% due to inadequate operating procedures\(^4\).
Table 1. Causes of escalator injuries with a comparison of the causes in the Taipei Rapid Transit Study and a review of USA escalator injuries\textsuperscript{6,8}. Some incidents have more than one cause.

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<th>Taipei Rapid Transit Study</th>
<th>USA Escalator Review</th>
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<tbody>
<tr>
<td>Falls</td>
<td>89.6%</td>
<td>75%</td>
</tr>
<tr>
<td>Entrapment</td>
<td>5.7%</td>
<td>17%</td>
</tr>
<tr>
<td>Other</td>
<td>8.3%</td>
<td>5%</td>
</tr>
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Table 2. Contributing factors in the cause of escalator injuries in the Taipei Rapid Transit Study\textsuperscript{8}. Some incidents have more than one contributing factor.

<table>
<thead>
<tr>
<th>Contributing Factor</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>Carrying out another task</td>
<td>19.6%</td>
</tr>
<tr>
<td>Loss of balance</td>
<td>13.4%</td>
</tr>
<tr>
<td>Not holding the hand rail</td>
<td>10.7%</td>
</tr>
<tr>
<td>Unhealthy Passenger (mostly intoxication)</td>
<td>9.3%</td>
</tr>
<tr>
<td>Stuck by another passenger</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

As discussed previously, people navigating through airports are as or more likely to be exposed to common contributing factors as people navigating through rapid transit stations. People are most commonly injured on an escalator while carrying out other tasks. This is an important finding as many people using airports are carrying out other tasks as they navigate through the airport. Adjusting luggage and attempting to find their way are just two examples of tasks that commonly distract individuals on airport escalators. Unlike children, adult females are more likely (67.5%) to be injured than males\textsuperscript{8}. This difference is largely due to shoe related injuries in women aged 15-65 and due to the greater likelihood of women caring for other people while riding on the escalator\textsuperscript{8}. Shoe related injuries consist of falls from high heal shoes and entrapping a shoe in the side of the step. Shoe entrapment, in all age groups, is most frequently seen in people wearing pliable shoe, rubber boots and sandals rather than leather shoes and boots. The injury rate between sexes is reduced in women over the age of 65, where
men and women are injured at the same rate\textsuperscript{8}. The TSSA has found that seniors are consistently involved in 33\% of all escalator incidents, a finding that is also supported by the research in Taipei\textsuperscript{4,8}.

In 2005, the TSSA reported 476 escalator and moving sidewalk incidents\textsuperscript{4}. These incident rates have remained stable between 400 and 500 incidents yearly from 2001 to 2005\textsuperscript{4}. In the 476 incidents in 2005, eight of these were serious injuries and five of the eight injuries involved seniors. An airport escalator safety program should focus on minimizing the risk of injury to the elderly because of the disproportionately higher frequency and severity of injuries to seniors. Other risky behaviors such as carrying luggage, caring for others and improper riding techniques should be considered when reducing the risk of injuries to adults of all ages.

2.3 – Escalator Injury Tracking at the Calgary International Airport

The Calgary Airport Authority has been tracking escalator related injuries since the airport’s management was transferred from Transport Canada in 1992. Figure 2 shows the number of escalator injuries per age group at the Calgary International Airport during 1997 to 2006. It shows that the vast majority of people who are injured are seniors over age 54. Adults, 20-54 years old, are the next most commonly injured and finally children are least commonly injured. There are between eight and seventeen escalator related incidents per year at the Calgary International Airport. This data is consistent with the findings of the TSSA and the Taipei Rapid Transit System in regards to injury population and frequency of escalator injuries.
During the ten year period between 1997 and 2006, Calgary International Airport has experienced a rapid increase in the number of passengers that pass through the facility. When the yearly incidents was divided by the annual passenger counts an incident rate was calculated to be between 1.0 and 2.3 incidents per million passengers, or an average of 1.35 incidents per million passengers (Figure 3). This ten year trend shows that the incidents have slowly decreased at the Calgary Airport. Although slightly higher, this incident rate is close to the rate found in Taipei of 0.815 incidents per million passengers through the system.
The increased number of escalator incidents at the Calgary International Airport may initially suggest that the airport’s escalators are less safe than in Taipei. It is likely that airport users are less familiar with the airport than rapid transit users, which could account for the increase in the Calgary International Airport incident rate compared to the Taipei incident rate. Most rapid transit users will use the system several times a week, while most airport users are not frequent flyers. The requirement for longer and more convoluted trips in airports may also skew the airport statistic because people will then ride more escalators in the airport. Since airport trips are rare, meeters and greeters will often join the person traveling when they are arriving or departing on a flight. This adds additional users to the airport’s facilities, but meeters and greeters are
not included in passenger statistics. They may be involved in escalator incidents, but are not reflected in the passenger statistics, further skewing the airport data.

The demographics of an area impacts the number of meeters and greeters in a given airport, thus making comparisons between individual airports difficult. There are several examples of how cultural differences can make navigating an airport difficult, but one simple difference can impact how passengers walk through an airport. In North America, people tend to favor walking on the right side of the hallway, similar to driving on the right side of the road and, therefore, tend to enter on the right side of the escalator. Having the escalator entrance on the left instead of the right, without some separation of the entrance and exits, causes user confusion in those accustomed to the North American standards. The opposite is true in places where people drive on the left side of the road. These people must adapt to the North American custom of right side dominance. This adaptation is frequently first required while a person navigates an airport just after arriving from overseas. Trips through mass transit systems tend to be quick, requiring few steps; while trips through airports tend to be longer, requiring more steps. These longer trips require more frequent use of the airport’s escalators and increase the exposure to the risk of escalator injury. These factors help to explain why people appear to be more likely injured on an escalator at the Calgary International Airport than in the Taipei Rapid Transit System.

The Calgary Airport Terminal was built in 1977 and over the past thirty years has grown to more than double its original size. Much of the original design has been reconfigured in subsequent renovations, but fixed features such as stairwells, elevators and escalators have remained nearly untouched. Escalator injury incident investigations
have concluded that the busiest escalators do not necessarily generate the greatest number of injuries. The proximity and visibility of the nearest elevator seems to be a better predictor of escalator injury rates. If airport users are unfamiliar with the location of an elevator, they often choose the riskier, but quicker escalator option. Relocating escalators and elevators may be impossible in a pre-existing building, but improved way finding remains a viable option in a pre-existing building.

3.0 – Solutions to Reduce Injuries Associated with Escalators

It has been suggested that it is necessary to “... educate both health care workers and parents about escalator-related trauma to prevent further injuries”7. In addition, it should be noted that the people who own and maintain the escalators also require sufficient education about escalator-related traumas in an effort to prevent further injuries.

3.1 – User Education Programs

The US Consumer Product Safety Commission has seven points to help make escalator use safer (Table 3). Public education attempts to change the behavior that can lead to escalator injuries. These include awareness of entrapment issues, proper adult supervision, and teaching young children safe and proper escalator use3. For example, children two to four years old tend to slide off and not step off when learning how to use escalators7. Public safety messages should be reinforced, and appropriate signage placed at the entrance to every escalator. The TSSA also provides public safety programs to help change risky behavior associated with escalators and moving sidewalks4. Many large city transit systems, such as the Toronto Transit Commission,
have public awareness courses that target local schools and have information available on their web pages.

Table 3. US Consumer Product Safety Commission Safety Alert\textsuperscript{10}.

<table>
<thead>
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<tbody>
<tr>
<td>1. Loose shoelaces, drawstrings, scarves, and mittens can become entrapped.</td>
</tr>
<tr>
<td>2. Always hold children’s hands.</td>
</tr>
<tr>
<td>3. Do not permit children to sit or play on steps.</td>
</tr>
<tr>
<td>4. Do not carry children in strollers, walkers or carts.</td>
</tr>
<tr>
<td>5. Always face forward and hold handrails.</td>
</tr>
<tr>
<td>6. Avoid edges of the steps where entrapments can occur.</td>
</tr>
<tr>
<td>7. Learn where the emergency shut-off button is.</td>
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Unfortunately, public education programs do not provide sufficient and specific instruction to best address the airport user. Airport users tend to use the airport infrequently and are often from different countries. Locally based public education programs do not reach many of the airport users and frequently do not focus on the contributing factors that cause injuries on an airport’s escalators. A supportive role in a community-based escalator public education program will offer only minimal positive results within the airport. Signage that reinforces the escalator safety messages are more helpful than involvement in community based education programs.
3.2 – Side of Step Gap Injuries

The most common point of escalator entrapment in an escalator is between the side of the step and the balustrade skirting (Figure 4). This type of entrapment has been described in the scientific literature since the mid-1960s\textsuperscript{3}. An example of a side of step entrapment injury occurred when a young girl had her hair entangled while trying to retrieve a coin she had dropped\textsuperscript{3}. The solution to this issue is to decrease the gap between the side of the step and the balustrade skirt\textsuperscript{5}. Decreasing the gap between steps can also help to reduce the less common entrapment which occurs between steps (Figure 5)\textsuperscript{5}. The American Society of Mechanical Engineers (ASME) recommends that the step to skirt distance be no greater than 3/16" (4.8mm) wide\textsuperscript{11}. In the Taipei Rapid Transit system, they have further reduced this to only 1/16" (1.6mm) wide. This distance reduces the risk of entrapping misguided little fingers in the gap. Reducing the gap width is an expensive and time consuming renovation and this may not be feasible for some pre-existing escalators. A practical cost effective alternative is to install a “brush guard” just above the gap to passively separate people from the gap (Figure 6)\textsuperscript{5}. The Taipei Rapid Transit System uses a combination of the brush guard and a narrowed gap of 1/16" (1.6mm) to reduce entrapment injuries. This appears to be highly successful because the Taipei Rapid Transit System reports that only 5.7% of their injuries are caused by entrapments, which is much less than the standard entrapment injury rate of between 15% and 20%\textsuperscript{6,8}. In addition to reducing gaps and brush guards, newer escalator steps have added yellow stripping along the gap between the side of the step and the skirting to highlight the hazards associated with these gaps (Figure 7).
Figure 4. Photo diagram indicating side of step gap.

Figure 5. Photo diagram indicating gap between stairs.
Figure 6. Photo diagram indicating brush guard covering the side of step gap.

![Brush Guards](image)

Figure 7. Photo diagram indicating yellow banding along the side edge and leading edge of an escalator step.

![Yellow banding on Stairs](image)
3.3 – Comb Plate Injuries

Comb plates are designed to remove larger items from the stairs to prevent the items from being ingested by the escalator mechanism. Unfortunately, comb plate entrapments cannot be eliminated by reducing the gap between the comb plate and stair to the same extent as at the side of the step. Comb plates require frequent inspection and repair and can become damaged without notice. Currently it is a requirement to change comb plates whenever two or more adjacent teeth are missing although this may become stricter in the near future. Any larger break greatly increases the likelihood that items can become entrapped. Smaller items can become lodged between the stair and comb plate and damage the comb plate which becomes a hazard to escalator users. Alternating the colour of the comb plates makes the transition more visible and alerts users to the transition (Figure 8). As mentioned, some newer steps have a yellow strip along the leading edge of the step, helping to further improve the visibility of the transition (Figure 7). An emergency stop button should be readily accessible at the threshold to stop the escalator and prevent further injury in the event of a comb plate entrapment\textsuperscript{7}. The ASME recommends that emergency shut off buttons be placed at the top and bottom of each escalator\textsuperscript{11}. For longer escalators or moving sidewalks, consideration should be given to install additional emergency shut off buttons midway. Some airports use a device similar to the emergency brake pull in trains. Quickly stopping the escalator is important because it stops further injuries to the person caught in the comb plate and it eliminates the complication of other riders piling up at the end of the escalator attempting to escape or step over the fallen rider.
Another common solution is to have recorded messages warning riders that the escalator or moving sidewalk is coming to an end. This has proven to be beneficial, but the benefits have to be balanced with adding additional background noise to the airport terminal. Repetitive voice messages are a frequent source of customer complaints.

3.4 – Luggage Carts and Trolleys on Escalators

Trolleys should not be permitted on escalators due to the inherent concern for passenger safety and the associated user inexperience. Some airport trolleys are specifically designed for escalators, but the items stacked on the trolley may come loose as the trolley descends or ascends. Luggage may fall off the trolley on an escalator, striking people on the escalator below. Baby strollers should also be discouraged on escalators as many of the newer strollers are used to carry both the
child and luggage. There have also been serious instances where babies are improperly secured in a stroller and fall out as the stroller descends on an escalator.

A reasonable balance should also be found for the use of wheelchairs on moving sidewalks and more particularly on escalators. Disabled athletes in wheelchairs may have no problem riding escalators safely. Other less skilled users could create serious hazards by losing control of the wheelchair, jamming the wheelchair against the sides or blocking the escalator entrance or exit. This could result in serious injuries to the disabled person, their attendant and other riders on the escalator.

Signage is a valuable, although passive option to restrict carts on escalators, but installing posts mounted at the entrance of the escalator actively modifies the unwanted behavior making it virtually impossible to take a trolley on the escalator (Figures 9 and 10). Installing entrance posts is a cost effective escalator retrofit, but the post must be sufficiently secured to be able to withstand the frequent and significant forces of passing users. In contrast to trolley users, people using wheelchairs or walkers are familiar with the consequences of using an escalator and rarely are involved in incidents. Gradually inclined sidewalks, inclined slopes and specially designed “trolley-friendly” escalators can also be installed and offer appropriate options for airports in the attempt to minimize the risk of incidents with carts on escalators.
Figure 9. Photo diagram indicating signage for prohibiting carts.

Figure 10. Photo diagram indicating posts at the entrance of an escalator.
3.5 – Direction of Travel Injuries

The direction of travel, either ascending or descending an escalator, is not a contributing factor for escalator injuries. However, injuries do result from people attempting to enter an escalator that is moving in the opposite direction. People from countries that drive on the opposite side of the road instinctively chose the incorrect escalator when visiting North America. Signs over the escalator entrances and exits that say “enter here” and “do not enter” can help to prevent this type of accident (Figure 11). These signs are better if they use international symbols rather than words and are green for the entrances and red for the exits. The use of green and red colors, indicating “go” and “stop”, can be incorporated into the threshold lighting (Figure 12).

Figure 11. Photo diagram indicating way finding signage for the entrances and exits of escalators.
3.6 – Regular Preventive Maintenance

Regular maintenance is also imperative to keep the escalator working well. During maintenance inspections and repairs, the lighting levels, wayfinding signage and warning devices should be checked to ensure that they are working as expected. An escalator preventive maintenance program should be based on the manufacturer’s recommendations and the airport’s escalator maintenance technician. A thorough review of regular preventive maintenance is beyond the scope of this paper, and therefore not discussed.

3.7 – Airport Design Creating Injury Risks

Airports present some unique operational challenges and human factors that require specific escalator safety protocols. Jet-lagged passengers, heavy passenger flow volumes following the arrival of an aircraft, and passenger flow choke points can all increase the escalator rider’s risk of injury. Jet-lagged passengers tend to be less attentive to using an escalator safely. Excess visual stimulation should be eliminated...
around escalators and limited only to way finding signage. Distracting and highly stimulating advertising should not be installed over escalators. When a flight arrives, there is a flood of people that typically travel in the same direction. Escalators are designed to move a significant number of people, but once they become crowded, they tend to become increasingly unsafe.

Escalators used to exit an aircraft should be designed to handle peak volumes and not simply average volumes. When escalators are close to choke points, such as security inspection points, escalators can become very dangerous. This was observed in a particular Canadian airport where the escalator is positioned just prior to the primary Canada Customs screening point. One evening, several aircraft disembarked at virtually the same time sending a number of passengers to the Canada Customs area at one time. There was only one customs officer on duty in the primary screening area, so arriving passengers began to line up for processing. Unfortunately, as the line started to grow, the arriving passengers bypassed the typical waiting area and the line of people started to quickly back up to the escalator. Even as several other customs officers arrived to process the arriving passengers, incoming passengers continued to bypass the waiting area. Eventually the line backed up to the escalator and it became increasingly difficult and uncomfortable to get off the escalator while people continued to enter the escalator. Well before there were any injuries, the escalator was stopped and the crowds of passengers were processed through the primary screening area. If the escalator had continued operating, people would have eventually been unable to get off the escalator creating a dangerous back-up of passengers. Several operational protocols were in place to prevent this type of incident, but unfortunately the protocols
did not work as designed in this case. As an airport terminal becomes busier, it becomes necessary to establish some additional operational protocols. In this case, airport authority employees, security and volunteers must play an important role in improving passenger flow at this potential choke point. Ultimately, if the escalator was not close to the choke point, this type of incident would not have occurred, highlighting the importance of escalator placement in reducing injuries.

4.0 – Designing Escalators and Moving Sidewalks in New Terminals

It is a rare privilege to design and build an airport terminal with the latest safety features and it is an even rarer privilege to design a building that is flexible enough to suit the safety needs of both the present and the unknown future. This paper has focused largely on retrofits and renovations to help make existing airport escalators safer. The following are some considerations, beyond minimum code requirements, for the construction of a new terminal building. An airport manager would benefit with some familiarity with ASME A17.1/CSA B44 - 2007 Safety Code for Elevators and Escalators when installing a new escalator.

As discussed, escalators should be installed as far from potential choke points as possible. Having an escalator continue to “feed” people into a congested area is a significant hazard, which is costly and/or requires extensive manpower to rectify. Ensure that every escalator has an easy and apparent elevator access option available to those airport users who wish to avoid the escalator^8. To reduce the risk of falls at the ends of the escalator reduce the transition radius to make the transition more gentle^{12}. The transition radius is the distance it takes to move from a 30 degree incline to no incline.
Also, lowering the escalator’s speed from 125 feet per minute to 100 feet per minute will reduce the incidence of balance related falls\textsuperscript{12}. The escalator steps should have a minimum width of 32 inches (0.76 meters) to allow easy lateral movement on a stair, and in higher capacity escalators it is beneficial to further increase the step width\textsuperscript{12}. There should be three flat steps at the entrance and exit transitions with a larger track radius of not less than 2.6 meters at the top end and 2 meters on the bottom end\textsuperscript{12}. This will make it easier for passengers to enter and exit the escalator without incident. Some newer escalators have handrails that travel at the same speed as the stair, so the rider does not have to adjust hand positioning during the escalator ride\textsuperscript{12}. Ensure the escalator gaps are as narrow as possible between the stair, skirting and adjacent stair and that brush guards are in place. There should be two emergency stop buttons, alternating coloured comb plates and entry and exit signage installed at either end of the escalator. These features will increase the up-front costs, but they will reduce incidents and the overall lifetime escalator costs. An inherent moral responsibility to protect the public and the reduction of the risk of litigation explains why these safety features are well worth their cost.

5.0 – Litigation

Justifying the cost of installing higher quality escalators or retrofitting existing escalators with additional safety features may be challenging, when all departments are competing for a share of a finite amount of money. The argument for escalator safety features may seem trivial in comparison to new machinery, the latest technology or marketing new airline routes. Escalator safety is assessed through risk management by
balancing the risk of exposure and the costs of mitigating that risk. Insurance companies make a living through risk mitigation and the cost of these escalator safety features should be viewed as insurance for the airport. As mentioned earlier, an airport terminal with as few as five escalators could expect an escalator related injury every year. Although, this may not always result in litigation, there is still the cost of processing the incident, investigating, follow-up and documentation. Based on the TSSA data presented in this paper, it is possible to estimate the number of escalator incidents in a given airport. Serious incidents and accidents are calculated from the number of escalators within an airport. Using this data, one could estimate how often the airport is exposed to liability from an escalator accident. Based on an airport terminal with twenty-five escalators, one could argue that a serious injury will occur every nine years that could potentially expose the airport to an extensive legal process. The cost of installing the recommended safety precautions becomes a more appealing option once factored against the cost of a protracted legal case.

In 1994, there were two cases of young children involved in escalator entrapment injuries reported by the Washington Post. Both of these cases were similar because of the region, year and circumstances involved in each case. The first case was a three year old child who was awarded $15,000 US for a leg entrapment injury which occurred while sitting on an escalator. The second case was a two year old child awarded $218,000 US for a hand injury after a shoe lace became trapped and the child tried to pull it out. Other than the limb affected, the major difference between these two cases was that in the first case neither parent was supervising the child at the time of the accident. Negligence by the individual or the caregiver impacts the financial
compensation and ultimately the airports financial exposure. In contrast, lack of supervision plays a role in 71% of stairway falls in young children\textsuperscript{13}, but in only 31% of escalator injuries\textsuperscript{7}. Therefore, it is highly beneficial to demonstrate caregiver negligence when it occurs because it is transfers much of the airport’s exposure back on the caregiver. Showing due diligence by regularly maintaining and adding safety features to an escalator can somewhat reduce the airport’s exposure to litigation, but demonstrating negligence by the person injured can greatly reduce the airport’s financial exposure.

Considering that human factors account for 83% of escalator injuries, establishing user negligence is beneficial. The human factors that most commonly cause escalator injuries include: carry out other tasks, loss of balance, not holding handrail and playing\textsuperscript{8}. These can be easily demonstrated with video evidence. Security cameras have the added benefit of capturing injuries while they happen. Good video evidence is frequently sufficient to nullify bogus claims. Intoxication and poor shoe choices can be counteracted with immediate and thorough investigation at the scene of an escalator injury\textsuperscript{8}. It is prudent to report every known incident, because there is no guarantee which incident will result in a claim. As part of the incident report the functioning status of the escalator should be recorded at the time of the incident. All records should be saved for at least two years after the incident or until the person is twenty years of age whichever is greater.
6.0 – Conclusion

Escalators and moving sidewalks are an important part of maintaining passenger flow in larger Canadian airports. While their benefits far outweigh the risk to user, the risk should be reduced to as low as reasonably practicable (ALARP). A good airport escalator safety program must be based on an understanding of the mechanism of injury and the populations most commonly involved in escalator related injuries. Preventive measures, described in this paper, can then be used to reduce the potential for future injuries. These preventive measures are best included during the design stage, but it is also beneficial to update pre-existing escalators with added safety devices. Skirting brushes, alternating coloured comb plates and entrance/exit signage are some low cost escalator safety retrofits that have been proven to be highly effective in reducing injuries in segments of the population that are commonly injured. If an incident does take place, quick and complete incident reporting including video evidence may significantly reduce the airport’s exposure to unjustified claims. Based on information presented in this paper, the probability of an escalator injury can be determined for virtually any airport. This can be used to competently justify the airport’s risk of an escalator injury and support an argument for the cost of minimizing the exposure. The cost of processing an injury claim and the moral responsibility of the airport operator must be balanced with the cost of safety upgrades to escalators and moving sidewalks. An airport escalator safety program based on research and proven technology is cost effective and improves escalator safety for the travelling public.
Literature Cited


13. Chiaviello, CT; Christoph, RA and Bond, GR “Stairway-related Injuries in Children” Pediatrics, Volume 94, Number 5 November 1994.