AN EVALUATION OF STAIRWAY DESIGNS FEATURED IN ARCHITECTURAL RECORD BETWEEN 2000 AND 2012

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Abstract
This paper discusses an evaluation of stairway designs featured in Architectural Record, a leading architectural professional journal, over a thirteen-year publication period (2000 to 2012). Images of stairways were classified as either hazard-free or hazard(s)-present using a hazard identification checklist, and the frequency of visible design hazards was tabulated. A total of 578 stairways were scanned in articles and advertisements, of which 78 (13.5%) were product advertisements. Sixty-one percent of the stairways had at least one visible design hazard including nearly half (47%) in product advertisements. The three most common hazards in stairways were inadequate handrails (161, 27.8%), excessive length of stairway flights (74, 12.8%), and low visual contrast on tread edges (73, 12.6%). The high prevalence of stairway design hazards in the professional literature indicates a need for improved professional education and media attention to safe stairway design.

Keywords: Architecture; Stairway Safety; Evaluation Research; Hazard Identification Checklist; Environmental Design; Design Education.

INTRODUCTION
Designing stairways is a ubiquitous part of architectural design. By today's standards, stairways should be designed and constructed to prioritize safety and usability for people of all ages and abilities. In the U.S., stairway trips, slips, and falls result in nearly 1,900 deaths (NSC, 2011) and 1,300,000 hospital emergency room visits per year (Pauls, 2011a). The high incidence of stairway accidents is common not only in the US but also in many other countries including Canada (Pauls, 2011b), the U.K. (Roys, 2011a), Japan, and Sweden (Templer, 1992; Scott, 2005). In all these countries, building regulations include many requirements for safe design and construction of stairways yet there are still a large number of accidents. What are the causes of this public health problem? Can architectural research do anything about it?

Causes of stairway falls include risky behaviors, poor maintenance, and design failings (Templer, 1992). Risky behaviors include running, using electronic devices on stairways, and carrying things that obscure one’s view or change the dynamics of balance. Maintenance causes include defective stairway features (e.g. loose treads, broken lighting), unsafe materials on the tread surface (e.g. ice, worn surfaces), and poorly conceived countermeasures intended to reduce falls (e.g., peeling of applied non-slip surfaces). Behavioral causes can be reduced by raising awareness of the risks of using stairways and thus increasing user caution, but experts argue that such actions may not be sufficient to mitigate the risks posed by design and construction of stairways since these risks are often not noticeable to users (Roys, 2001). Examples include ungraspable handrails and irregular step geometry.

A reasonably safe and usable stairway is defined in the literature as one that meets safety standards for three basic criteria: step geometry, handrails, and stairway visibility (Pauls, 2013). Step geometry should be uniform in shape and dimension and facilitate gait (Novak et al., 2016; Pauls & Barkow, 2013; Johnson & Pauls, 2010; Jackson & Cohen, 1995); handrails should be both reachable and graspable (Maki, 2011; Dusenberry et al., 2009), and stairway components, i.e., steps, handrails, landing and headroom, should be clearly visible and perceivable to users (Archea et al., 1979; Sloan, 2011). These basic features are even more important for people in need of additional stair climbing support, i.e., people with physical, sensory, or cognitive limitations. Incorporation of these features leads to a universal design approach that would be safer for a wide range of people (Steinfeld & Maisel, 2012; Pauls, 2012).
Stairway design plays an important role in health promotion due to the health benefits of stair climbing as a form of exercise - improved weight control, lowered cholesterol levels, and improved cardiovascular fitness (Lee et al., 2012; Lewis & Eves, 2001). Research has demonstrated that building design can promote more frequent bouts of walking (Boutelle et. al., 2001; Nicoll, 2007; City of New York, 2010), but stairways are believed to have a higher potential for increasing light to moderate physical activity in part due to their presence and potential for use in every multistory building (Mansi et al., 2009; Cohen, 2013). This has led to the development of policies to improve the appeal of stair climbing, particularly in the U.S. where more than 66% of adults are obese (Brown et al., 2009). Policies include New York City Mayor Michael Bloomberg's executive order for architects to use “Active Design” strategies by designing highly visible, easy to access, and attractive stairways in new and renovated city buildings (City of New York, 2013). However, experts have also cautioned that increased stairway use could increase the number of stair-related injuries (Pauls, 2012), thus architects and builders need to pay careful attention to the design details and construction of stairways as they encourage use of stairways to improve fitness.

Despite some advances in knowledge of stairway safety, potentially hazardous stairway design practices seem to be prevalent. This suggests that the knowledge available on design of stairways is not being utilized. A scan of stairway images across a broad spectrum of media, including popular professional journals and internet blogs, will uncover many recently constructed stairways with identifiable and well known safety hazards that increase a person’s risk of tripping, slipping, or falling. The stairways found in the media often have features that clearly do not meet safety standards, yet they were somehow not only constructed but also highlighted in feature articles and websites as exemplars of architectural design practice. Building codes in the U.S., including the International Building Code (IBC), American National Standards Institute (ANSI), and ADA Accessibility Guidelines (ADAAG), have made stairways in newly constructed public buildings safer by requiring architects to design stairways that are part of a means of egress to meet highly technical requirements; however, the criteria for stairways that are not part of a means of egress or in private dwellings are less stringent. With few exceptions, the IBC requires at least two general means of egress and not less than one that is “accessible” in buildings (ICC, n.d.), which means that stairways that are not part of a means of egress in any multistory building could have design features that would be considered hazardous and still comply with building regulations. Many unusual features are being incorporated into stairways such as glass stair treads, interactive sound and light, treads at acute and obtuse angles, etc. that are not addressed by regulations at all. These stairways are often centerpieces of the design, or “feature stairways,” the most visible and most likely to be used by building inhabitants and visitors. The implications of these contemporary practices on safety are currently unknown.

We conducted a literature scan of stairways using Architectural Record, a leading professional architectural journal to investigate trends in stairway design practices. Professional journals are important to the field of architecture because they are a source of contemporary design ideas, product reviews, and continuing education for professionals and are often referenced during the research phase of projects (Borg & Gall, 1989 cited in Waugh, 2004). The purpose of this study was to examine current practices in stairway design as featured in the architectural press, assess the degree to which safe design practices are present, and identify issues that have not yet been addressed in stairway research. The results of this study suggest that safe stairway design practices should be supported by improved professional education and more media coverage on this topic. Several knowledge needs were also identified for further research in this field.

**METHODS**

**Sample**

We evaluated images of constructed stairways that were published in Architectural Record articles and advertisements between 2000 and 2012. Architectural Record was chosen because it is the oldest and most established professional architectural journal in the U.S. with a circulation of 115,155 (Ulrichsweb, 2014). This journal is considered an essential resource to architectural education and is included on the Association of Architecture School Librarians (AASL) Core List of 53 periodicals (2009 edition) (AASL, n.d.) – a list that is used as an evaluative criterion in the process of accrediting architecture degree programs by the National Architectural Accrediting Board (NAAB). Furthermore, Architectural Record has an h-index of 4 in the citation database produced by Scopus (SJR, 2014), which is the highest rating of any trade journal in architecture on the list (see Table 1).
Table 1: H-index of professional architecture journals on the AASL Core List covered in the Scopus database (Source: Authors).

<table>
<thead>
<tr>
<th>Professional architecture journal*</th>
<th>h-index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architect</td>
<td>2</td>
</tr>
<tr>
<td>Architectural Record</td>
<td>4</td>
</tr>
<tr>
<td>Architectural Review</td>
<td>1</td>
</tr>
<tr>
<td>Landscape Architecture</td>
<td>3</td>
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<tr>
<td>Lotus International</td>
<td>1</td>
</tr>
<tr>
<td>Planning</td>
<td>6</td>
</tr>
<tr>
<td>Preservation</td>
<td>1</td>
</tr>
</tbody>
</table>

*The Scopus database does not cover all titles on the AASL Core List. Note that Planning is the journal of the American Planning Association and does not have significant content related to building design.

**Design**

The study began as a class project by twenty-one graduate students in an ergonomics course at the University at Buffalo Department of Architecture. The class was divided into teams and assigned to scan the literature of different publication years. Each team developed a unique method of collecting and analyzing the stairways, including use of rating scales and checklists. Consequently the results of the project varied, but each team identified a significant number of stairways with safety hazards that provided insight into contemporary stairway design practices. These findings indicated that a more controlled study would be fruitful for identifying a gap in the application of research knowledge to practice. The authors used the student work to develop a new method to quickly identify common stairway design hazards, referring to the literature on stairway safety to validate the items on the list. A hazard identification checklist was organized into four categories: railings, steps, visibility, and other (see Figure 1). A systematic review was then conducted by a single researcher (the first author).

<table>
<thead>
<tr>
<th>Railing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handrail(s) not fully extended at top/bottom of flights</td>
</tr>
<tr>
<td>Missing/inadequate balustrade(s)</td>
</tr>
<tr>
<td>Missing/inadequate handrail(s)</td>
</tr>
<tr>
<td>Handrails too large/too thin</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>High/low riser-to-tread ratio</td>
</tr>
<tr>
<td>Irregular riser height and/or tread size</td>
</tr>
<tr>
<td>Narrow stairway width</td>
</tr>
<tr>
<td>Short tread depth</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low visual contrast on tread edges</td>
</tr>
<tr>
<td>Open risers</td>
</tr>
<tr>
<td>Poor stairway lighting</td>
</tr>
<tr>
<td>Distracting pattern on steps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive length of stairway flight</td>
</tr>
<tr>
<td>Inconsistency within the top/bottom steps</td>
</tr>
<tr>
<td>Oblique stairway shape</td>
</tr>
<tr>
<td>Obstruction on stairway</td>
</tr>
</tbody>
</table>

Figure 1. Stairway Design Hazard Checklist (Source: Authors).
Procedure
Every page in each issue of the journal was manually reviewed for images of stairways constructed in the U.S. Images that were readily discernible were documented using a scanner and/or digital camera. Small prints lacking sufficient details, and stairways located outside of the U.S. were excluded. Each image was cropped and inserted into a page template using graphic representation software. Evaluations were based solely on image content and guided by two principles: if a stairway image showed at least one condition listed in the hazard identification checklist, then it was classified as unsafe and ‘hazard(s)-present’; if the image did not show any of the conditions listed, then it was considered reasonably safe and classified as ‘hazard-free’. For each stairway, information on conditions observed, setting (public or residential) and image type (article or advertisement) was recorded on the checklist in spreadsheets, and the frequency of each condition on the list was tabulated. Some of the conditions in the checklist require precise measurements to ascertain their presence if deviations are only slight, e.g., high/low riser-to-tread ratio, irregular riser height and/or tread size. In this study, we only could identify obvious evidence of such conditions. Thus the results clearly understate the presence of unsafe conditions but a conservative estimate of frequency of problems is sufficient to achieve the goals of the research.

RESULTS
A total of 578 stairways were scanned over a thirteen year publication period between 2000 and 2012—of these, 78 (13.5%) were in product advertisements. The majority of the stairways in our sample were located in public settings (72.8%, n = 421). Sixty-one percent of the total sample of stairways (n = 355) had at least one obvious design hazard and were classified as ‘hazard(s)-present’—thus less than 40% of stairways in this study were considered reasonably safe (n = 223). Of those classified as hazardous, 62% were public (n = 219) and 38% were residential (n = 136) (see Figure 2). The results of the evaluation are presented in Tables 2 and 3. In advertisements, nearly half of the stairway products exhibited hazards (47%, n = 37) (see Figure 3).

The most frequently observed hazard category was railings, comprising 36% of all hazards documented. Visibility was the second most frequently observed hazard category (29.1%), followed by other hazards (19%), and steps (16%).

The three most common design hazards were missing or inadequate handrails (27.9%), excessive length of stairway flights (12.8%), and low visual contrast on tread edges (12.6%) (see Figure 4). While the vast majority of stairways showed only one (48%), two (32%), or three (15%) hazards out of sixteen that were included in this study, the number of hazards should not be used to rate stairway safety since a misstep or a fall can be caused by even one condition. Moreover, grievous and obvious conditions, like a steep stairway, with a long flight, lacking both handrails and balustrades, could be so obvious that users adopt a more cautious and attentive behaviour while using it or avoid using it. Evaluating the severity of problems on stairways in the sample was beyond the scope of this research.

The remainder of this section summarizes an evaluation of stairway design practices that were most commonly observed with references to the International Building Code (IBC)—the primary model building code adopted in the U.S. These building regulations are an indication of safety issues that are well known to governmental agencies and violations of design standards.

Missing or inadequate handrail(s)
Handrails serve multiple functions: visual cues to the stairway’s presence, directional guidance, postural stability, fall mitigation, and reducing conflicts in ascent or descent by cueing stair users to stay to the side, usually to the right on stairways in North America (Templer, 1992; Jackson & Cohen, 1995; Dusenberry et al., 2009). Best practice recommendations include the provision of handrails on both sides of stairways. The International Building Code (IBC) has exceptions to the requirement for handrails on both sides of stairways. Notably, residential stairways and spiral stairways; decks and patios are not required to have handrails at all; a single elevation change at an egress door and changes in elevations of three or fewer risers in dwelling units also do not require handrails (ICC, 2011). Compliance only with minimum standards and taking advantage of exceptions in the codes can pose significant safety risks, especially for people who require additional support for balance, like children and elderly people.
Table 2. Public stairways: result of an evaluation of stairways featured in *Architectural Record* (n = 421). (Source: Authors)

<table>
<thead>
<tr>
<th>Year</th>
<th>Hazard-free</th>
<th>Hazard(s) present</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 (n = 35)</td>
<td>21 (60.0%)</td>
<td>14 (40.0%)</td>
</tr>
<tr>
<td>2001 (n = 30)</td>
<td>17 (56.7%)</td>
<td>13 (43.3%)</td>
</tr>
<tr>
<td>2002 (n = 40)</td>
<td>15 (37.5%)</td>
<td>25 (62.5%)</td>
</tr>
<tr>
<td>2003 (n = 37)</td>
<td>17 (45.9%)</td>
<td>20 (54.1%)</td>
</tr>
<tr>
<td>2004 (n = 36)</td>
<td>16 (44.4%)</td>
<td>20 (55.6%)</td>
</tr>
<tr>
<td>2005 (n = 26)</td>
<td>12 (46.2%)</td>
<td>14 (53.8%)</td>
</tr>
<tr>
<td>2006 (n = 39)</td>
<td>14 (35.9%)</td>
<td>25 (64.1%)</td>
</tr>
<tr>
<td>2007 (n = 26)</td>
<td>16 (57.7%)</td>
<td>11 (42.3%)</td>
</tr>
<tr>
<td>2008 (n = 27)</td>
<td>15 (55.6%)</td>
<td>12 (44.4%)</td>
</tr>
<tr>
<td>2009 (n = 38)</td>
<td>12 (31.6%)</td>
<td>26 (68.4%)</td>
</tr>
<tr>
<td>2010 (n = 21)</td>
<td>10 (47.6%)</td>
<td>11 (52.4%)</td>
</tr>
<tr>
<td>2011 (n = 29)</td>
<td>16 (55.2%)</td>
<td>13 (44.8%)</td>
</tr>
<tr>
<td>2012 (n = 37)</td>
<td>23 (62.2%)</td>
<td>14 (37.8%)</td>
</tr>
</tbody>
</table>

Table 3. Residential stairways: result of an evaluation of stairways featured in *Architectural Record* (n = 157). (Source: Authors)

<table>
<thead>
<tr>
<th>Year</th>
<th>Hazard-free</th>
<th>Hazard(s) present</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 (n = 15)</td>
<td>1 (6.7%)</td>
<td>14 (93.3%)</td>
</tr>
<tr>
<td>2001 (n = 14)</td>
<td>1 (7.1%)</td>
<td>13 (92.9%)</td>
</tr>
<tr>
<td>2002 (n = 11)</td>
<td>0 (0.0%)</td>
<td>11 (100.0%)</td>
</tr>
<tr>
<td>2003 (n = 13)</td>
<td>3 (23.1%)</td>
<td>10 (76.9%)</td>
</tr>
<tr>
<td>2004 (n = 12)</td>
<td>3 (25.0%)</td>
<td>9 (75.0%)</td>
</tr>
<tr>
<td>2005 (n = 13)</td>
<td>1 (7.7%)</td>
<td>12 (92.3%)</td>
</tr>
<tr>
<td>2006 (n = 13)</td>
<td>3 (23.1%)</td>
<td>10 (76.9%)</td>
</tr>
<tr>
<td>2007 (n = 18)</td>
<td>1 (5.6%)</td>
<td>17 (94.4%)</td>
</tr>
<tr>
<td>2008 (n = 22)</td>
<td>4 (18.2%)</td>
<td>18 (81.8%)</td>
</tr>
<tr>
<td>2009 (n = 10)</td>
<td>2 (20.0%)</td>
<td>8 (80.0%)</td>
</tr>
<tr>
<td>2010 (n = 5)</td>
<td>0 (0.0%)</td>
<td>5 (100.0%)</td>
</tr>
<tr>
<td>2011 (n = 5)</td>
<td>2 (40.0%)</td>
<td>3 (60.0%)</td>
</tr>
<tr>
<td>2012 (n = 6)</td>
<td>0 (0.0%)</td>
<td>6 (100.0%)</td>
</tr>
</tbody>
</table>

Stairways in *Architectural Record* n = 578

- Hazard-free
- Hazard(s) present

- Public n = 421
- Residential n = 157

Stairways in Product Advertisements n = 78

- Hazard-free
- Hazard(s) present

- Public n = 60
- Residential n = 18

Figure 2. An evaluation of stairways featured in *Architectural Record* by setting. (Source: Authors).

Figure 3. An evaluation of stairways featured in *Architectural Record* product advertisements by setting. (Source: Authors).
Figure 4. Frequency of stairway design hazards in Architectural Record feature articles and product advertisements between 2000 and 2012 (Source: Authors).

Although the handrail is probably the most important safety device for stair users, almost 30% of the stairways in this study (n = 161) had at least one or more of the following conditions: unprotected stairways at one or both sides (see Figure 5), three or fewer stairs that were potentially difficult to see or expect without handrails as visual cues, wide stairways without intermediate handrails distributed across the width, and non-continuous handrails that were interrupted by newel posts or other objects in environments where releasing grip of the handrail poses a risk.

Handrail(s) not fully extended

A basic principle of safe stairway design is that the handrail must be available for the user to grasp on the first step and maintain a grip all the way to the last step. Handrails are most heavily used at the top and bottom of flights; 70% of stairway accidents occur at these locations, demonstrating their importance (Templer, 1992). This research also suggests that handrails are needed most at landing areas. Handrail extensions or continuous handrails on intermediate landings can help people identify the start and end of the stairway, gain stability when mounting and dismounting flights, and make a safe transition in gait between landings (Danford & Tauke, 2001; Bakken et al., 2007). With proper installation, extended handrails can support people as they adapt their gait to various changes, e.g., in view, illumination, route direction, and floor surface (Templer, 1992) while entering and leaving stairways. U.S. building codes require handrails in a means of egress stairway to be continuous for the full length of each flight and extend at least 12 inches (305 mm) beyond the top and bottom riser, plus the width of one tread for the bottom extension. These extensions, however, are not required in dwelling units, assembly areas, the inside turn of stairways, and in existing stairways where they would be an obstruction (ICC, 2011).

In our study of new or substantially remodelled building projects, 20 (3.4%) stairways clearly had handrails of insufficient length, including those that truncated before even reaching the top or bottom riser (as seen in figure 5) and handrails that did not extend across the landing, primarily in public buildings.
Handrails too large or too thin

After losing balance a stair user searches for support in an attempt to arrest a fall by reaching out and grasping a handrail (Templer, 1992). Handrail shapes that are too wide or too thin are not ergonomically designed to be grasped firmly and thus may not be effective during falls. A round handrail between 1.25 inches (30 mm) and 2 inches (50 mm) in diameter is generally accepted as the best shape and size for gripping because it provides a "power grip" in which the thumb can touch the fingers in the shape of the letter ‘C’ (Maki et al., 1998; Bakken et al., 2007; Dusenberry et al., 2009). Narrow or other shapes that require a “pinch grip” are generally not recommended (Maki, 2011).

Handrails were visibly too wide or too thin in 18 (3.1%) stairways. Rectangular shaped handrails made of metal or wood in 2x4 or 2x6 flat configuration were types of poor handrail shapes commonly observed. Railings with smaller cross-sections were used in minimalist designs, probably for their reduced obtrusiveness. As with irregularities of step geometry, the study methods did not allow measurement of handrails, and we could only see grievous conditions so this deficiency is probably underreported.

Inadequate balustrade(s)

Although balustrades are intended to protect sides of stairways, there is more leeway in regulations for creativity in baluster design than in railing design, and several types of hazards have been identified. Open spaces between balusters that are greater than 3.5 inches (90 mm) are areas where a child's head could slip through or body parts could become caught during a fall (Archea et al., 1979 cited in Templer, 1992). Large gaps under the bottom rail allow objects to slide or roll off stairways to areas below. Sharp edges of balusters pose risk of bodily injury. Horizontal rails and other balustrade attributes that can be climbed also pose risks for children and even adults (Templer, 1992).

The balustrade was missing or inadequate in 14 (2.4%) stairways. The majority of these (86%, n = 12) were located in private homes where the practice of omitting balusters was common. The findings provide evidence of a stylistic preference toward minimalist-aesthetic in stairway design. In the simplest of designs, only a railing was provided with no protective balustrade. Another variation on this theme was a railing with balusters spaced several stair treads apart and large enough for a person to easily fall through.
Low visual contrast on tread edges
The tread's leading edge is a key attribute in stairway design because it is crucial to help users perceive elevation changes between steps, place their foot accurately, and control their gait (Archea et al., 1979; Templer, 1992; Zietz & Hollands, 2009; Den Otter et al., 2011). Stair users visually scan a stairway using their foveal and peripheral visions. Depending on the user's attentiveness and the complexity of the environment, people may either look at the stair edges continuously, or they may glance at the stairs periodically. Most people scan the stairway at least once every seven steps taken (Templer, 1992), and rarely look directly at the stair edges. Miyasike-daSilva et al. (2012) suggest that this scanning behavior can be attributed to increased use of peripheral vision over foveal vision during the stair use task. Stair edges that are high in contrast levels can help make each step more visible in both central and peripheral zones of vision (Templer, 1992; Den Brinker et al., 2005).

U.S. building codes advise architects and builders to provide high visual contrast on stair tread edges mainly for people experiencing low vision (ICC, 2011), but this design practice can obviously benefit those with good vision as well.

In this study, low visibility of stair tread edges was observed in 73 (12.6%) stairways. This design practice was the third most commonly observed unsafe condition in stairway images. The results suggest that many stairways are clearly designed with a priority on aesthetics at the expense of safety. Stairways with a monochromatic color scheme for risers and treads are commonly used to achieve a cohesive visual form, uninterrupted by distracting elements (see Figure 6). Glass stairways and reflective tread materials contributed to the prevalence of this condition as well (see Figure 10).

Open risers
There are two primary types of step and riser design: closed riser stairways (required within a means of egress in building regulations) and open riser stairways (not permitted within a means of egress by building regulations). Closed risers prevent feet and canes from accidentally slipping under treads, and they keep children, pets and objects on stairways from falling through (Templer, 1992). The solid barriers between treads also block distracting views in the background behind the stairway that may draw the user's attention away from the steps during ascent and cause tripping. Open riser stairways can cause a person to feel a sense of insecurity about the stair climbing task (Scott, 2005) and thus are not generally
recommended. Where permitted, open riser stairways must be installed so that a 4 inch (100 mm) sphere cannot pass through openings (ICC, 2011).

In this study, we observed 64 (11%) open riser stairways with overstimulating surrounding views that would cause visual distractions (see Figure 7).

Figure 7. Views through open risers — Isabella Stewart Gardner Museum in Boston, constructed 2012. (Photo courtesy of Bruce T. Martin Photography).

**Poor stairway lighting**

Lighting affects our ability to perceive steps, railings and hazards in stairways (Templer, 1992). Research has demonstrated stairways with lower illumination levels have a higher incidence of falls. Carson et al. (1978) found that incidents were twice more likely at 2 foot-candles (22 lux) of light than 8 foot-candles (86 lux) (Templer, 1992). Hamel et al. (2005) found that older adults did not lift their legs as high off the steps while descending the stairs as young adults did, resulting in inaccurate stepping patterns, which makes them more vulnerable to missteps in low light conditions. Kasahara et al. (2007) found that under low illumination, older adults restricted their eye movements and visual scanning patterns to foveal regions because they required more time to focus on the steps directly ahead, and thus causes them to disregard visual information in the periphery.

Current lighting recommendations for stairways in the U.S. range from 10 to 20 foot-candles (108 to 215 lux) (Templer, 1992; IES, n.d.). Good stairway lighting should also include even illumination on the handrails and walking surfaces so that shadows do not fall on the stairway as well as indirect illumination that does not shine into the user's field of view and cause glare (Templer, 1992).

In this study, 28 (4.8%) stairways were noticeably dim or unevenly lit. Although it was impossible to actually measure the illumination in the photographs, the conditions we identified were very obvious without such measurements. Moreover, professional photographers carefully illuminate their subjects. Thus the frequency of this hazard is probably underreported.

**High or low riser-to-tread ratio**

The slope of the stairway should allow comfortable walking gaits to reduce the risk of falls (Novak et al., 2016). Sometimes, however, the stair pitch is skewed toward steeper slopes in order to fit the stairway in a building or to increase the economic efficiency of the building plan, i.e., more rentable or saleable space. Research shows there are more falls on stairways as steps depart from a “best practice” standard of a 7
inch riser (180 mm) and 11 inch tread (280 mm) (Templer, 1992). In particular, Johnson and Pauls (2010) demonstrated that stairways with high risers cause more falls. Ascending users require a higher leg lift and more strength to raise their body up and forward, and descending users shift their weight forward and downward for longer distances while balancing on one tread in each footfall (Templer, 1992).

The U.S. building code allows exceptions to the “7-11” design standard for residential and spiral stairways. In residences, riser heights can be a maximum of 7.5 inches (190 mm), and tread depths can start at 10 inches (255 mm). Spiral stairways can have higher risers measuring up to 9.5 inches (240 mm), and treads can be more narrow at 7.5 inches (190 mm) depth measured 12 inches (305 mm) from the narrower edge (ICC, 2011).

We could not identify stairways that depart from optimal conditions due to slight variations as they are not enough to be noticeable in photographs. We were only able to identify obviously excessively steep and shallow stairways and found that 35 (6%) stairways met the screening criteria, ranking fifth in stairway design hazards. Since we could not measure risers and treads, this result is most likely underrepresenting the frequency of stairways with non-optimal riser-to-tread ratios.

Irregular riser height and/or tread size

The riser and tread must be uniform for every step in a stairway flight. People tend to expect well built (and safe) stairways with uniformity of tread and riser dimensions throughout their length, an expectation that leads to low attention to the steps while climbing stairways (Templer, 1992). A continuous run of rectangular treads that are equal in shape and size can help reduce the risk of falls by allowing stair users to have a more consistent and natural gait as opposed to treads with varying sizes and shapes that force alterations of gait while climbing the stairway. It is well known that dimensional irregularity of steps is a leading cause of stairway falls (Jackson & Cohen, 1995; Cohen et al., 2009; Johnson & Pauls, 2010). To help counter this problem, the building code requires uniform risers and treads where the largest riser/tread minus the smallest riser/tread in a flight of stairs cannot exceed 3/8 inches (9 mm) (ICC, 2011). But, this tolerance may be too great. Research shows that even a slight irregularity of as little as 1/4 inch (6 mm) can interfere with the user’s gait (Johnson, 2011). In construction, dimensional variations of between 1/6 to 1/4 inch (4 mm to 6 mm) are commonly observed (Roys, 2011b).

Twenty-four (4.1%) stairways in our sample had obvious irregularities in step geometry, including combinations of rectangular and winder treads. In Figure 8, the stairway is also located in a residential setting, in which residents are likely to pay even less attention to the changes in tread size than if they encountered it in an unfamiliar setting. As with other criteria, the study was limited in that we could not actually measure risers and treads so it is probably underrepresenting the frequency of irregular step dimensions. But, Figure 8 demonstrates that irregularity of shape is easy to observe from photographs.

Narrow stairway width

The clear width between walls, railings or the sides of stairways should accommodate the expected traffic flow and reach ranges for handrails (Templer, 1992; Levine, 2003). Adequate space on stairways is needed to move safely and comfortably, including a pacing, sensory and buffer zone for the user (Templer, 1992). The minimum code requirement for straight flight stairway widths is 36 inches (915 mm) for areas with an occupant load of 50 or less and 44 inches (1120 mm) for 50 or more people (ICC, 2011). Templer (1992) argues 38 inches (965 mm) is needed for minimal comfort; 56 inches (1420 mm) allows people to walk side-by-side in heavy clothing; but, a 69 inch (1755 mm) stairway width includes clearance between heavy clothing and tolerance for tracking error and thus is most comfortable to the user. Codes allow spiral stairways to be narrower, 26 inches (660 mm) in width (ICC, 2011), but these stairways do not provide the standard 11 inch (280 mm) minimum tread depth at the inside walking line; the minimum stairway width would have to be 6 feet, 9 inches (2.06 m) wide to provide adequate winder tread depth at the walking line (Templer, 1992).

In this study, 16 (2.8%) stairways were very narrow. It was noted that many of these also lacked handrails or had winder treads. Narrow stairways without handrails can create problems in implementing handrail retrofits in the future since handrails take up at least 3 inches (75 mm) on each side of stairways (Templer, 1992), and this would reduce the effective width of the stairway even more. A narrow stairway width in winding configurations forces the user closer to the inside radius where the tread becomes too small for safe walking (see Figure 8).
Figure 8. Irregular tread size, narrow stairway width, short tread depth — duplex apartment in New York City, constructed 1999. (Photo courtesy of Michael Moran Photography).

Short tread depth
Slips due to overstepping treads in descent are the most frequent type of stairway falls (Bakken et al., 2007; Johnson & Pauls, 2010). The risk of overstepping increases where treads are too narrow to accommodate the length of the foot. This condition is often found along the inner radius of winder or "pie-shaped" treads on stairways that turn or spiral. U.S. building codes require an 11 inch (280 mm) tread as the minimum effective depth for accessible stairways in public buildings (ICC, 2011). Treads on residential stairways are currently allowed to be smaller, with a minimum of 10 inches (255 mm), and on spiral stairways, treads are allowed to be even smaller with a 7.5 inch (190 mm) minimum depth measured 12 inches (305 mm) from the narrower edge (ICC, 2011). Although the study methods did not allow us to measure the steps, we found 17 (2.9%) stairways had treads that were obviously too narrow for proper foot placement (see Figure 8).

Excessive length of stairway flight
A reasonably safe stairway should consist of at least three risers so that it is noticeable and people do not accidentally walk into it (Templer, 1992). But, it should also not have too many steps without a landing since the risk of falling on stairways increases with longer durations of exposure. Moreover, excessively long stairway flights require greater energy expenditure over a longer time of exertion, which can lead to a sudden loss of balance for older adults, people with arthritis and those with low stamina who need to stop and rest periodically. There are psychological factors to consider as well. Using stairways can be a daunting task for people with physical or cognitive limitations. A long continuous run of steps can contribute to the fear of falling, especially among elderly people (Tiedemann et al., 2007). To encourage more stairway use for fitness, stairways should not induce avoidance behavior by appearing too challenging and dangerous.

Although the IBC (2012 edition) does not specify the number of steps in a flight of stairs, it is recommended by the National Safety Council (NSC) that a landing be provided at every tenth or twelfth tread (Reese, 2009). Older people in a focus group study reported that they can negotiate twelve steps maximum in between landings (Ormerod, 2011). In our study, we applied a tolerance of three steps. Thus stairway flights with more than 15 steps were identified as hazardous, including the stairway with twenty-two risers shown in Figure 9. An excessive length of stairway flight was the second most common design hazard (12.8%, n = 74).
DISCUSSION

Our scan of current stairway design practices suggests that the knowledge available on stairway safety is not being applied consistently in buildings featured in a leading trade journal. Although standards and codes lag behind the science, that does not excuse the adoption of best practices, for example, contrasting tread edges and easy to grasp handrails, that have been well known for decades. 

Architectural Record, like most professional design journals, features buildings that have unusual formal characteristics, including stairways, presumably to attract readership and maintain an innovative edge in the field of architectural journalism. The stairways featured are not the prosaic stair towers hidden away in the bowels of buildings, nor those in the buildings with which most citizens are familiar, e.g., most stairways in schools, formula driven office buildings, health facilities, and spec houses. One could argue that the vast majority of stairways in buildings meet code requirements and are relatively safe. Yet our study demonstrated that, in contrast, most stairways selected for publication are potentially dangerous based on well-known causes of stairway accidents. The results suggest that many architects are either unaware of the risks associated with stairway use, or they choose to ignore good practices to achieve other goals, such as getting their work published, attracting clients, or recognition by their peers (e.g., creating the lightest looking stairway ever). The higher value placed on form is not confined only to those architects whose work is featured in the architectural press. From our own personal experience, as a recent student and a design instructor who has attended hundreds of studio reviews, many design studio instructors encourage students to make stairways unusual and even scary! The focus on form over function can be perpetuated in design studio courses by failing to pose a design problem that requires a design solution (Maturana, 2014). Some clients clearly agree with this value orientation, or such stairways would not be approved for construction. They may even urge their architects to create a “wow” experience. But, it is the architect’s responsibility to ensure that buildings are safe and resist such pressure.

We selected Architectural Record for the source of examples because it is currently the most established, well respected, and well-read professional architecture journal in the U.S. and thus serves as an “opinion leader” in the professional print media. Interestingly, we found only two feature articles about stairway safety in our scan of thirteen years of issues (Talarico et al., 2000; Arsenault, 2012), suggesting communication about safe stairway design is limited in industry news and trade magazines in the print media. Considering stairways are important parts of architectural design and given the liability risks associated with their use, it would be reasonable for professional journals such as Architectural Record to
feature more articles about good stairway design practices or at least provide some criticism of the unsafe stairways featured in their journal. These articles could also focus on the health benefits that stairways provide building users. Such content could influence architects and builders to design and build more carefully.

We found that 61% of the stairways had at least one visible and well-known design hazard, including almost half (47%) of the stairways in product advertisements. Although the prevalence was lower in advertisements, the result raises questions about company standards for product safety, e.g., how well-informed are companies on their products' safety features?

The most common design hazards were defective or missing handrails, long stairway flights, reduced visibility of tread edges, open risers, and non-optimal riser-to-tread ratios. The results are aligned with the top priority-issues that have been identified in stair research and outlined by Pauls (2011c): handrail and guard shapes, step geometry, tread characteristics, landing size, stairway widths, and factors related to visual perception and cognition. We also found a much higher proportion of unsafe stairways in homes (87%) in comparison to those in public buildings (52%), which alludes to the “greater need” of improving stairway safety in homes – the site of 90% of falls (Pauls, 2013). Unsafe behaviour is more likely to occur in a residence due to the presence of children and the familiarity of the setting. Yet, residential stairways are typically less regulated, and so given the leeway, it seems architects experiment even more in these settings and are clearly given client support.

The results suggest a need for improved professional education on stairway safety for architectural journalists, in continuing education, and in the academy. While this study cannot be used to attribute negligence to the majority of practicing architects, it does suggest that opinion leaders in the profession place a higher priority on aesthetics than on safety and health or are lacking in knowledge about this important aspect of design. To counter the pervasive impact of media, more attention to building codes and design standards, including their limitations with respect to research knowledge, should be incorporated into school curricula to ensure that students learn best practices. Moreover, attention should be given to improve and expand stairway safety requirements in building regulations to protect the unsuspecting public, including housing. Public educational programs should also include emerging issues like the impact of obesity on stairway falls (Pauls, 2012), reduction of distracted walking accidents caused by use of electronic devices (Caya, 2014), and effects of new technologies and design concepts, like glass stair treads and minimalist handrails, on user safety. A review of the legal practices surrounding stairway accidents and risks of legal action against architects, building owners, and product manufacturers should be an important topic for continuing education and professional practice courses. In particular, due to gaps in the regulations, professionals and students need to learn best practices so that they are aware that standards and codes lag behind the research knowledge. Best practice examples would not only inform professionals, but also encourage interest in building safer stairways.

Our systematic research raised important issues for future investigation. First, open risers were of particular interest to us because the use of this feature is almost entirely based on aesthetic considerations. There is no practical reason for using open risers other than saving material, but the materials used on most open riser stairways, for example glass or stainless steel, clearly indicate that cost was not a major consideration in their design. In particular, understanding the impact of open riser stairways on both visual performance and gait is an area that needs research attention. Second, Templer suggested that long stairways are safer because they cause people to use more attention on the stairs (1992). In other words, in a short stairway flight, the user may glance at the steps only at the transition at top and bottom but not in between, but, on a long stairway, they will glance at the steps one or more times in addition. Is this hypothesis correct? Research on how users distribute their attention in relation to stairway length would be useful to determine optimum lengths of flights from an attention perspective. In addition, it would be useful to know the impact of long treads on users’ perception of effort and benefits from stair walking. Do long stairways discourage use and therefore reduce opportunities for improving fitness? Third, winder treads are inherently more dangerous than straight stair treads, but they are used by architects to create sinuous stairways or to fit stairways in a small space. What is the impact of winder treads in places where environmental distractions cause people to turn their attention away from the stairs that are changing in size and shape as they descend or ascend? Finally, new technologies allow stairways to be constructed of unconventional materials. In this study, glass stairways were associated with low visibility of the tread edges (see Figure 10). Although nonslip treatments are available for glass used as a walking surface, where users are likely to track water in during bad weather, these treatments may not be adequate.
Research is needed to determine if glass tread edges can be easily perceived and whether non-slip surface treatments are adequate to prevent slipping, especially under wet conditions.

Figure 10. Open glass treads, irregular tread shape, missing handrails — duplex apartment in New York City, constructed 2001). (Photo courtesy of Roy Wright Photography).

There were several limitations to this study. The results represent stairway design practices in the U.S. Examples from buildings in other countries were not included because design standards differ across jurisdictions and countries. Thus findings cannot be generalized to buildings in other countries. Further, we only studied one professional journal. However, this journal covers noteworthy buildings and the work of leading architects. These same buildings are routinely featured in most other architecture trade journals. A comparative study could determine if other sources are doing a better or worse job in promoting safe stairway design. A comparison of Internet sources with print media would also be useful. Today the Internet may actually play a more important role in forming professional opinions. Like other traditional publications, Architectural Record itself maintains a major Internet presence, including a free site with limited content, additional in-depth material available to subscribers for a fee, and daily news sent by email. The content is similar to the print version although there are more buildings featured. Blogs about architecture like Dezeen and Architizer are proliferating and becoming more professional in their content over time. Searching websites and blogs is, of course, much easier than the print version and we intend on expanding our research to this material. We are anticipating that the trends we observed in this study will be similar or magnified even more on the Internet versions of publications and on blogs. For example, Dezeen has a prominent feature of “extreme staircases.” We could not find one example in their collection of photos that would be considered a “safe” stairway by our criteria. This feature is actually focused on promoting the most extreme of stair design ideas at the expense of safety!

Another limitation of the study is that the buildings featured in media are not representative of the vast body of stairway construction. Architectural Record and other architectural trade journals focus primarily on high-end buildings, especially in the residential sector of the building industry. A similar study of buildings not included in journals would be useful to find out if the findings here are widespread in professional practice. The buildings featured are primarily those that are designed by well-known or established architects who may have more leeway to depart from conventional practice than the average architect. Other architects may be more knowledgeable and careful about safe stairway design. Yet, the architects whose work are featured in the journals are role models for the profession and one may ask whether they
should take that responsibility seriously. They are like star athletes or performers whose fashions and lifestyles often set norms for their fans.

Although the study was carefully designed to maintain accuracy, the stairways were evaluated by a single researcher, thus the ability of other researchers to get the same results with the checklist is still not known. The method used also has some significant limitations on access to content. Stairway images could have been misleading or distorted during professional photography and editing; details could have also been hidden due to camera angles. But, given the simplicity of the method used and our conservative approach to evaluation, our findings are probably an underrepresentation of the problems found in current practices. With proper training in the use of the checklist and the evaluation task, it is also likely that good inter-rater reliability can be achieved using the checklist.

The checklist used in this study provides a tool for future research and practice. In future work, we also hope to extend the literature scan to learn more about the reader's perception of stairway designs. We also intend to assess the degree to which readers of professional journals can recognize unsafe stairway design features and whether, for the architects, it influences their own design practices, and for clients, their communications with design and construction professionals. And, through two other threads of research, in a laboratory setting and systematic observations of stairways in use, we are already taking up some of the gaps in our knowledge about safe stairway design that we observed in this literature scan.

In conclusion, this research raises questions about professional values that deserve more research. Is valuing form over function common among the opinion leaders in the architectural profession? Could stairway safety be only one example of this value orientation? Such a value orientation may be an occupational hazard – a by-product of developing strong design values and getting noticed. But, if it contributes to mistrust of the profession and the need for increased vigilance on the part of clients and building regulatory officials, it should be addressed in professional education and in the professional media. Most importantly, the unwary public is clearly put at risk without their knowledge when safety issues are neglected. How can such practices be changed? It is a public health question that the profession, including accrediting authorities, need to consider. We hope that with education and awareness, architects will take more interest in designing safer stairways that at the same time are attractive and innovative. These goals are not mutually exclusive.

ACKNOWLEDGEMENTS
The contents of this report were developed under a grant from the Department of Education, NIDRR grant number H133E100002. However, those contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government.

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