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MSc Program "Building Science & Technology"

Improving Child Safety in Residential Buildings via Architectural Design and Technology Integration

A master's thesis submitted for the degree of "Master of Science"

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Vienna, June 2007

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Affidavit

I, **Roberta Jiraschek**, hereby declare

1. That I am the sole author of the present Master Thesis "Improving Child Safety in Residential Buildings via Architectural Design and Technology Integration" and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. That I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, June 2007

Signature

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ACKNOWLEDGMENTS

First of all, I want to thank my family, my parents and parents-in-law for their support and to believe in me. I thank my mother who always brings me great ideas, my sisters who always show me a different point of view and my father who always supported me without restrictions.

I would like to thank Professor Mahdavi, for his advices and patience and mainly for the opportunity and support he gave me through these months to make this great step in my carrier and life. I thank all his Institute for the material support and friendship.

And most of all, I thank my husband for his eternal love, patience and to be my inspiration. He always teaches me how to be a better person. I thank him for his useful critics to my work and to his support in all situations.

ABSTRACT

This work intends to create design guidelines based on the classification of design elements in residential buildings according to risk levels. It suggests the inclusion of safety aspects in children's immediate environment by better design solutions and technologies which can help to prevent home accidents that mainly affect children aged between 0 and 4 years.

The guidelines could help to create new building and design standards for architects and the building industry. They are based on research, conducted mainly in the European Union and the United States of America, into regulations and programs focusing on the prevention of home accidents.

This work may be of benefit to parents, manufacturers, the building industry, architects and governments. Parents may benefit, obviously, because they get information on how to decrease the number of hazards within their children's environment. It may help manufacturers improve their safety standards. Consumers may choose from a range of safer products. It may prompt the building industry to create safer designs and products thus avoiding liability claims. It may inspire architects to a more safety-oriented design. Finally governments could reduce health costs – in Austria alone, for example, more than € 3.4 billion a year are spent on home and leisure accidents.

Keywords: children, accident prevention, architecture and technology, hazards, risk assessment, design guideline

1 INTRODUCTION

Statistics show that over 80% of registered injuries of children aged between 0 and 4 in Europe are the consequence of home accidents [IDB 2000]. Throughout Europe, 170 000 or 21% of all registered injuries involve people under 29 years; 26 000 children under 15 die from injuries every year in the European Union. This is the equivalent of 3 children an hour.

According to the European Child Safety Alliance, "home injuries" are injuries which occur either "in" or "around" a residence. This definition includes the inside of the residence, yard and garden, but it excludes roads around the residence and nearby parks.

1.1 MOTIVATION

International efforts to reduce home and leisure accidents involve several sectors. Health and environment departments must work together in the face of the statistics; however, an exact understanding of the accidents (how they happen, where, with whom etc.) and information on what is involved in those accidents (which building part, product, objects) is still missing and would be the task of a whole range of professionals.

Home accidents are an important and underestimated public health and housing issue. Homes can determine safety and health parameters, especially for small children, who have almost a 24h/day interaction with their home environment. This supports the importance of a safe and healthy residential environment.

Architects and other specialists of the building industry face the problem of recognizing potential design hazards and the need to create better building standards. After a literature review, I would like to point out some facts as a justification of this work:

FACT I – Little information is given on room types where accidents happen and the kind of building elements and objects involved.

Accident reports from ten different hospitals and emergency rooms world-wide were analyzed and 50% had no specific question about the part of the house where the accidents happened and the type of elements involved.

Bonnefoy WHO 2005 declared: “There is some data about the leading causes of death but they do not give any information about where and how the accidents occurred; especially no indication is given about the role of housing characteristics which lead to the accidents.”

The information available about the accident location and elements involved is definitely not representative for a complete overview. “When an accident happens at home, there is no real indication which building elements were involved,” the director of the Child and Youth Survey in Germany reported.

In the past two years many countries have developed programs and campaigns to reduce the number of residential accidents, most of them starting with the identification of hazards in the house. The intention is to create a valid database that shows the main affected groups and the main hazards. The first step is to evaluate the type of hazard which can be: housing hazards, behavior hazards, and product hazards.

Housing hazards refer to building elements and design, such as the constructional quality, design concept and all the fixed and movable appliances installed by the constructor or architect (fire detectors, handrail, furniture, stairs, window and door types) which can affect the likelihood of an accident and the severity of its consequent injury [WHO 2005].

FACT II - Private and public buildings have different building codes to prevent child accidents.

The analysis of the existing regulations on safety has shown the discrepancy between the public and the private sphere. Regulation targeting the reduction of injuries, especially concerning children, very often applies only to public institutions (for example pool fencing). As a matter of fact, a relatively low number of child accidents occur in public buildings, while over 80% of accidents happen at private dwellings. This indicates that those prevention practices used in public buildings could and should be integrated in building codes for residential buildings.

FACT III - Money and investments question – the reduction of the number of accidents

Safety is a need and right of every human being and a central duty of the state [Rauch-Kallat 2004]. Injuries and accidents are the main cause of death and a major cause of ill health and disability in children between 0 to 5 years old. It is also a major cost to health services across Europe [Towner 2004].

In Austria, approximately € 3.4 billion were spent to remedy accidents (not including material lost and indirect costs) in the year 2004; that means € 430 for every Austrian, or € 390 000 per hour in one year (Institut Sicher Leben 2004).

The cost-injury estimation involves several short-term items and as many other long-term items. In the short-term cost estimation, all injury treatments, other medical expenses and the child's recovery are counted. On the other hand, the long-term costs include lifetime of work lost, loss of life quality, future disability of the child to work, follow-up care costs, work that parents or other adults will have or won't have because of the child's disability (work losses), impact on children's and parents' productivity.

Not just the government could save money, but also manufacturers, parents and the building industry. Fewer accidents would happen and fewer liability claims would be made, apart from the fact that parents would do anything to have a safer home for their children.

FACT IV – Different standardizations of regulations in each country make it difficult to identify potential hazards and create a common standard.

Different standardization and building regulations in each country complicate the identification of most common problems inside dwellings. Some countries' legislations place emphasis on minor issues and ignore major problems, as pool fencing for example. Different regulations are barriers to creating a common and international standard.

In Italy for instance, the minimum standard for the height of a window is 1m, while in Germany it is only 80cm (and typically Germans are higher than Italians). This happens because the ministry in charge of this regulation is different in every country. In Germany, the Ministry of Transport, Construction and Housing is responsible for the legislation, while in the UK it is the Office of the Prime Minister.

There is not only diversity at an international level, but also a lack of action from the part of almost every health Ministry to implement regulations for the prevention of domestic accidents at a national level.

FACT V - Children are not treated as potential groups with regard to building codes; they are sometimes referred to as a particular group, but not treated as such.

Regulations on home safety do not target children in a special way. If children are mentioned, then only in the context of parents’ duty of supervision [Röbbel 2005].

Another fact is that in the past 15 years, a great improvement in building codes and building standardization to prevent accidents in elderly people took effect. The same hazards that cause accidents for older people were identified as hazards that cause accidents in children, because children are treated as part of the elderly’s age group when it comes to developing laws to avoid those accidents. But the physical and psychological development of a child is completely different from an elderly person. Children’s interactions with the environment and the way they face hazards make places that are deemed safe for the elderly a place full of hazards for children.

The EU’s new legislation – Built for all – which is to be approved by 2008 and includes urban accessories, new design approaches and new building codes to avoid accidents in elderly people while not excluding them of everyday life, unfortunately does not consider children as a potentially affected group.

FACT VI - There is a potential market for smart homes, housing and building technology to create safer residences and to make everyday life easier and more comfortable.

A survey on the potential market for smart homes, realized by Mark Pragnell, Lorna Spence and Roger Moore, examined consumers’ behavior and knowledge in about 1000 households. Safety, security features, central climate control and remote access are the most known and most desired features in terms of smart housing technology. Safety and security features appear to have the greatest appeal on consumers (70%).

In figure 1, data on the research shows the percentage of people who would like to use smart technologies. Most people (over 50%) affirm that smart technologies would be very useful, especially the possibility to control home devices when not at home and safety and security advantages of a smart home that can save time and effort.

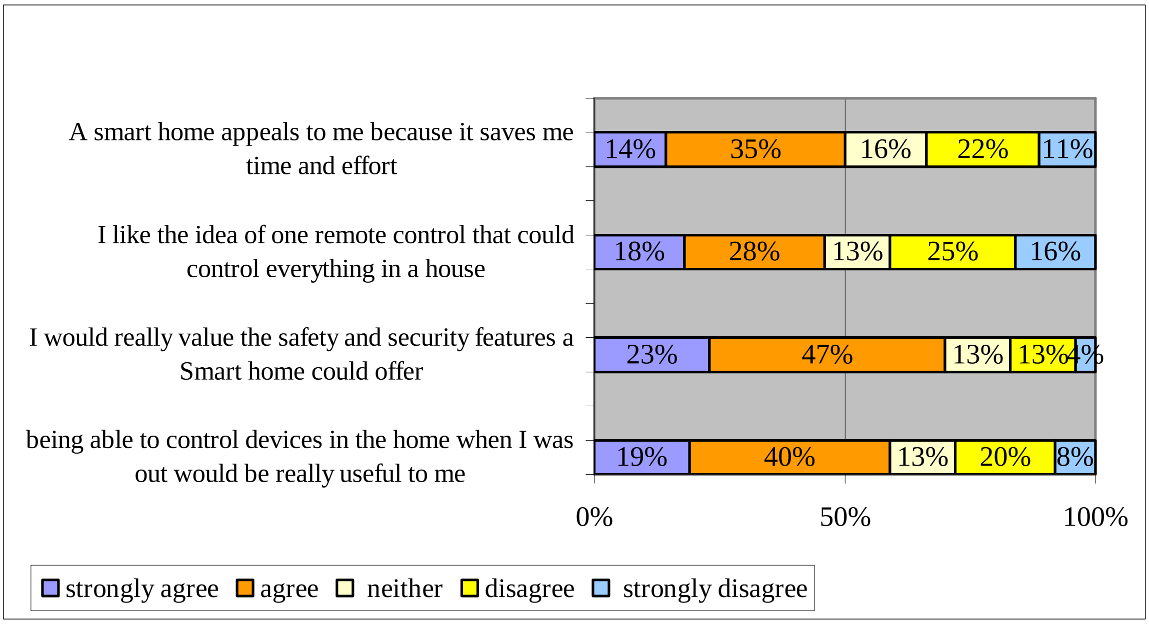


Figure 1: Views about Smart Home features [Moore, Pragnell, Spence 2004]

Figure 2 shows the present interest of people in smart homes. Apparently, there is a great interest in the technology; if price would not be an obstacle, most people would have it. The research also showed an increasing knowledge about smart home technologies and a significant interest in using it. The main concern nowadays is the complexity of introducing and using the technology and, of course, the price.

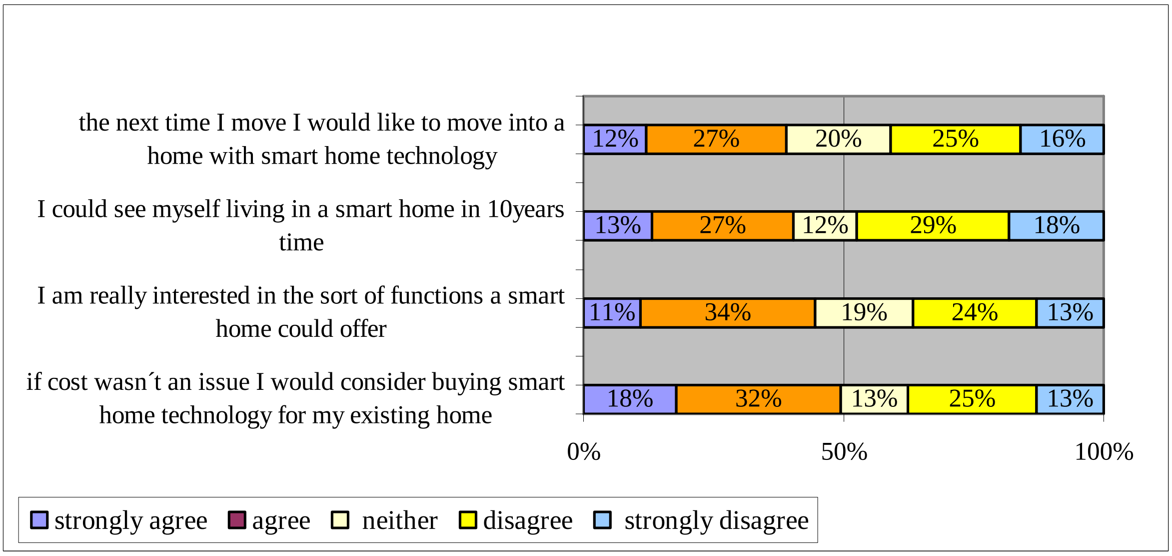


Figure 2: Interest in the Smart Home concept [Moore, Pragnell, Spence 2004].

Some experts claim that in 5 to 10 years, this technology will be affordable and accessible not just for persons with special needs, but it will be integrated in every residential design.

The popular idea of a smart home, according to surveys, is still to have "up-to-date" equipment such as DVD players, TV, PC, and Internet connections at home. On the other hand, the potential market for new technologies has been the subject of university researchers and industry and technology developers, indicating an enormous application area.

Once home automation systems become more and more popular, the standard residential construction has to adapt itself to the new technologies and housing concepts. The whole building project concept has to be updated; from the structural part, going through electrical and mechanical installations, up to the architectural design. Cooperation between architects, constructors and technology experts will surely be a part of the construction development from now on, aiming to provide safety, comfort and economical buildings through innovative solutions.

The idea is to automate life inside the home, identify users' activities and repeat them automatically, detect dangerous situations, react to them, anticipate users' "desires" and fulfill them. This involves not just sensors which recognize consumers' desires, but also modern software systems and electronic networking which interpret sensor activities and coordinate objects and equipments, operating without the need of direct human interaction.

An example is the Kitchen Sync, a project realized by MIT where all of the kitchen devices are connected and can be controlled both physically (with human interaction) and digitally (without human interaction).

Smart homes consist of an integrated network of devices and systems, which can detect each other and react alone or in a chain reaction. An important point is that switchers and other mechanical buttons are no longer the coordinators of a decision (e.g. turn on/off buttons). The switchers are no longer related to each device, but a network operates the devices in a pre-thought way. The direct relationship between users and devices will be substituted by a smart interaction system.

Following is a list of some technologies and interfaces used nowadays to control smart homes:

- Infrared remote controls
- Computers
- Internet
- Telephony
- Tone dialing
- Bespoke panels
- Voice
- Physical switches
- Optical registration
- Heat, movement, weight, lighting sensors

2 BACKGROUND

In order to prevent domestic child injuries as well as other injuries, it is important to have an appropriate data evaluation. As Dr N. Röbbel reported: At EU level, domestic accidents have still not been recognized as a major field for prevention activities. It has been stressed that there is the need that the commission of the EU strengthen these initiatives [WHO 2005].

In the course of the research it was found that most of the EU countries do not have specific reported data on child accidents, and especially, a database which could be compared and used for statistics.

The data on accident reports would come from emergency centers, hospitals, mortuaries, governmental programs, and usually cite the cause of the injury (for example falls and burns), the location (house, public space, school, traffic accident), age and gender of the patient, economical situation of the family, time and date of the accident and in some cases pre-reported accidents.

After the program HHSRS was started in the United Kingdom in 2004 to (re-)assess risks for residential properties, statistics show that the number of child accidents at home increased about 20% in two years. The simple explanation is that before the program was set in place, there were no general databases of accidents and most injuries were not registered.

Historically, the role of the general practitioner in child accident prevention and management has been poorly defined and presents an important topic for further investigation. Accidents are classified as health problems, but they cannot be solved by public health care alone.

Children may have accidents and suffer injuries because their environment or products may have hazards. Many accidents and, as consequence, injuries are preventable, hazards can be identified and eliminated.

Safety is sometimes more dependent on processes or services than on specific products or the environment itself, and an increasing number of standards is conceived for those aspects. The “performance standards”, as they are nowadays called, are recognized as a powerful means of reducing hazards. (In terms of safety, performance means minimization of product hazards).

Prevention programs and government initiatives (as for example new safety standards) can play an important role in prevention. Accident prevention is a fine example of an area in which the best results are achieved by cooperation.

In recent years, views on incorporating safety aspects into standards and legislation have become increasingly concrete. In particular, the European standards for the safety of machinery [ISO/TR 12100] and the new standards and legislation to prevent traffic accidents, which lead to an approximate 50% accident decrease during 15 years of the program, have been considerably successful.

As the Austrian Program for the Prevention of Unintentional Injuries recorded, the number of hospital admissions after home and leisure accidents has increased about 73% since 1980, while in the same period, the number of traffic and occupational accidents has decreased by half. This trend reflects the enormous efforts by governments and the private industry to prevent traffic and occupational accidents.

“Between 1975 and 2000 the causes of occupational injuries with fatal outcomes and the number of persons killed by traffic accidents has decreased enormously. In these fields many efforts have been undertaken by governments. This figure shows that with political willingness the reduction of injuries can be achieved”, the director of the Action Program Environment and Health in Germany said.

In 1989, concerned about growing evidence of the impact of hazardous environments on human health, the World Health Organization/Europe initiated a process to raise awareness and to start collaboration between sectors, particularly the health and environment sectors. It brought sectors together through ministerial conferences, inviting to work on common issues and to set up new programs.

An international meeting in May 2005 coordinated by the World Health Organization, joined experts in environmental, health and accident prevention to promote new policies for the European Union. The next meeting is scheduled to take place in Vienna, Austria, on 13-15 June 2007. There is a world-wide call for new programs and new incentives to improve accident statistics. Architects are environment designers and together with constructors and the building industry bear the responsibility to act as part of those prevention programs.

The need of collecting and matching data acquired by home surveys on the present hazards and health/ accident data is clear. Varying admission policies, different hospitalization procedures among countries, and disagreement in creating a common database makes information incomplete and incomparable. Data must be comparable in order to be used on an international and broader level. The goal is the evaluation of massive data for the creation of new international standards and an effective reduction of accidents

2.1 ACCIDENTS

2.1.1 Accident overview

According to the World Health Organization, an accident is a sudden, undesired, and unforeseen event resulting in a physical injury, for which medical assistance is sought at an emergency department or other patient hospital department.

The European Home and Leisure Accident Surveillance System – EHLASS – describes a home and leisure accident as an accident, which is not a traffic accident, nor an occupational accident, nor an injury due to violence or a self inflicted injury.

Accidents usually lead to injuries; most of them are temporary, but some permanent or deadly. Injuries can be categorized as intentional and unintentional. Intentional injuries include violence and abuse and represent 32% of all fatal injuries in the EU [Injuries 2006]. Unintentional injuries are the so-called accidents and appear as 68% of all fatal injuries. A second classification for injuries is by sector, e.g. work accidents are classified as occupational accident.

Figure 3 illustrates the percentage of unintentional injuries in each sector. Home, leisure and sports represent the leading sector in terms of number of accidents with over 60%, followed by 30% traffic accidents and 4% workplace accidents.

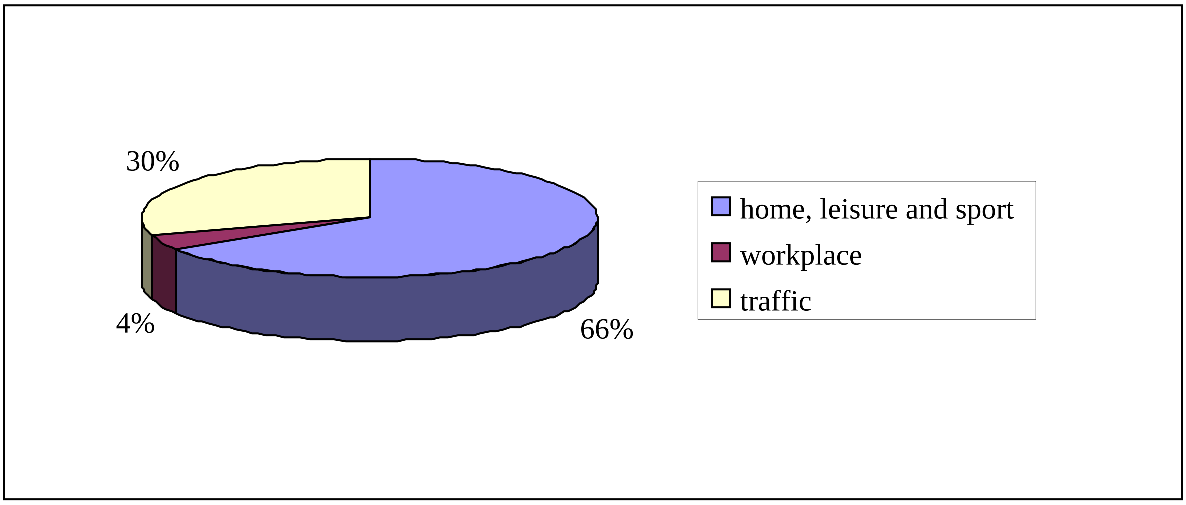


Figure 3: Unintentional Injuries by Injury Sector [Injuries 2006]

Injuries overall are the killer number one of young people and the third cause of death across all ages in the EU. In Europe, 170 000 persons under 29 years account for 21% of all persons injured and 26 000 children under 15 die from injuries every year. This is the equivalent of 3 children an hour. In Austria alone, 14% of all injury deaths concern children between 0 to 19 years old; 45% of hospital injuries admission and 43% of emergency department visits are due to home accidents, reports Mrs. Mathilde M. of the Austrian Injury Prevention Plan.

In Australia, injuries are the leading cause of death in children from 0-14 years, meaning more than 20,000 babies in less than six months were injured in accidents in 2002 and a massive 83% of them happened at home.

Figures 4 and 5 illustrate the major injuries that lead to death in the EU. The first one gives us an overall view, considering all ages. The second chart shows the major causes of death in children aged 1 to 4 years.

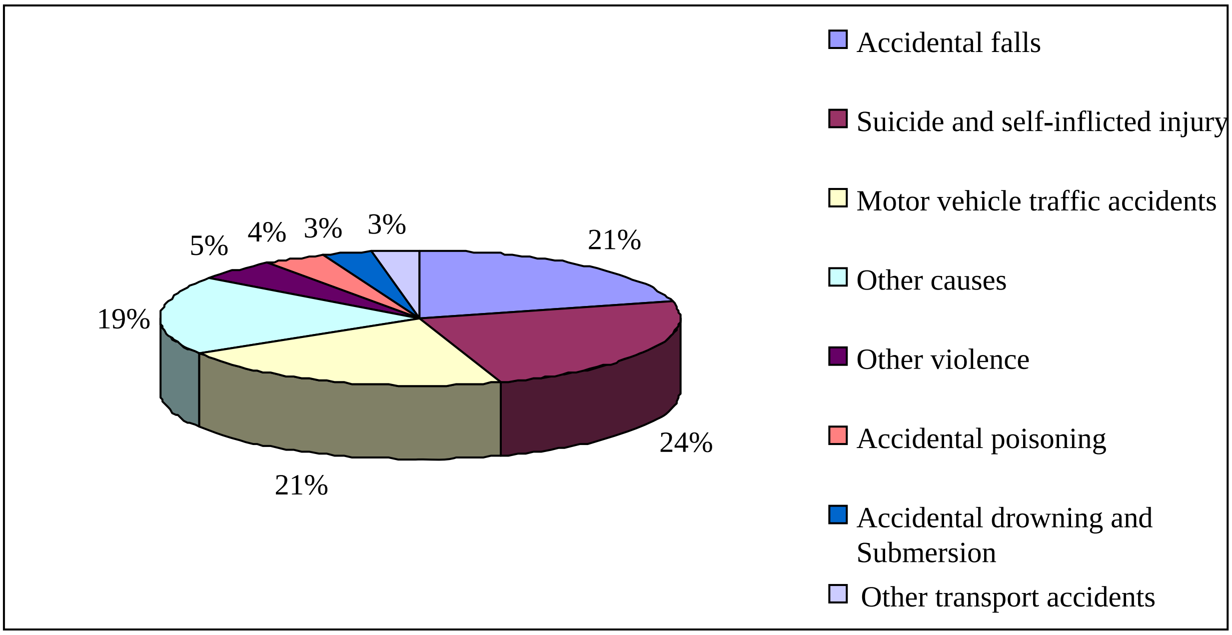


Figure 4: Causes of Death of fatal injuries in the EU – all ages [Injuries 2006]

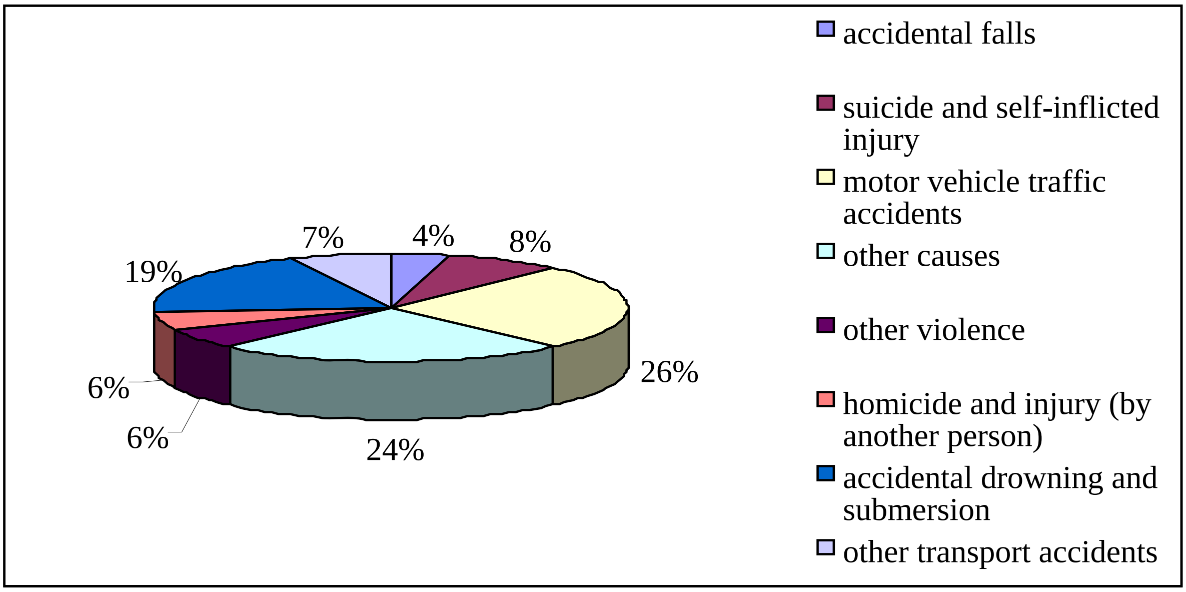


Figure 5: Causes of Death of fatal injuries in the EU – 1 to 4 years [Injuries 2006]

As the WHO reports, 84% of accidents in children between 0 and 4 years old happen at home. The explanation is simple: children at this age have almost all their activities at home, they spend over 70% of their time in the residential environment.
Home accidents tend to occur due to a combination of intrinsic factors, such as parents' or/and children's physiological qualities, and extrinsic factors, such as poor or inadequate design. Intrinsic factors often involve children's characteristics once they "develop" their physiological characteristics, and are directly related to the children's age.

Some intrinsic factors can be modified by new habits and education. On the other hand, most extrinsic factors involved in home accidents are related to the environment and objects. This kind of home accidents require active interaction, and there is a need of finding design problems and hazards and fixing them.

To make accidents easier to understand they are often classified by the "factors" which cause them:

- Factors related to the children – physical characteristics, development, gender, education

- Factors related to the environment and objects – design solutions, object hazards.

There are nowadays two “categories of preventive measures” to keep the risk of accidents under control:

- Active measures: Making sure the environment the children live in is protected (keeping windows closed, limiting children’s access to staircases with physical barriers)
- Passive measures: Educating children and attending to them; taking into account the children’s age-specific comprehension level

The likelihood of a child accident to occur is associated with some factors which include:

- Family condition – parents’ education, social and economical factors – indirectly related to children
- Hazard conditions associated with other factors – directly related both to children, environment and objects
- Child development – directly related to children
- Environment and products conditions – directly related to the residential environment and objects

2.1.2 Accidents and family conditions

As I mentioned before, the first step to actively identify hazards is to differentiate between housing hazards, behavior hazards, and product hazards. Behavior hazards refer to human factors that increase the risk of accidental injuries. This wrong behavior can be caused by carelessness, but also by lack of knowledge about possible hazards.

According to the National Institute of Public Health of Denmark, family, social and economical conditions are determining factors when addressing home accidents. For example, a survey carried out by the Institute established that the risk of child poisoning doubled, if the mother has a low school education.

The risk of burns appeared also twice as high for children living with a single parent and the risk of cuts was 16% higher in overcrowded dwellings. As a conclusion of the survey, the social factors should be taken into consideration when analyzing the association between housing features and accidents, as differences in accidents between dwelling types may at least in part be due to social differences.

Another interesting factor directly related to home accidents are characteristics of family culture. It was found, for instance, that the risk of burns from hot water is four times greater in certain Asian groups than in European families, because those Asian groups drink much more tea than Europeans.

2.1.3 Accidents and hazard conditions

A survey realized in cooperation with the British Office of the Prime Minister discovered that with regard to the building characteristics there is a strong correlation between dwellings where a surveyor (trained person who inspect dwellings) identified potentially relevant hazards and buildings in which accidents have occurred. This reinforces the strong relationship between accident rates and housing conditions.

For the same age group and social factors, it was established that persons having three “housing problems” (or three potential hazards identified by the surveyor) are twice as likely to have an accident than those having none of the specified problems. Examples of those “housing problems” were poor lighting, construction defects in stairs (handrails, steps), unrepaired appliances, wrong material use.

For example, wherever the surveyor judged the kitchen utensils or equipments to be hazardous, 30% of the residents reported cuts, while 20% reported cuts in the dwellings considered to have insufficient lighting. For falls, the highest accident rate (25%) occurred in dwellings judged to have hazardous bathrooms, including “slippery wet tiles”, hazardous floors and carpets, staircases and doorsteps. Furniture correlated with falls at over 15%. By comparison, only 9% of falls occurred where no hazards were reported.

2.1.4 Accidents and child development levels

The search for independence, autonomy, self-confidence, social cooperation and the growing interaction between child and environment can sometimes make an adult-safe environment challenging for a child.

The types of accidents children have are directly linked to their level of development. As a consequence, there are particular things to watch out for depending on the age of the child. For example, children between 3 and 5 years start to use furniture to play with, such as bunk beds, resulting in the fact that at this age the number of falls and cuts is considerably greater than in the first year of life.

To understand and respect each child's individual abilities is one of the first steps to prevent accidents. As the child grows, hazards change, and as a consequence, risk assessment changes. It has to be clear that children do not intentionally misuse products or expose themselves to potentially dangerous surroundings. They interact with them in ways that reflect normal childhood behavior and development.

Another relevant point is that children must be treated as a particular group when it comes to products, design and standardization. One has to understand that children are not small adults and also cannot be treated as elderly persons, as their physical qualities, capacities and proportions are completely different (children also show different physical characteristics, and a completely different interaction with the environment).

Main accidents according to children's age group:

Between birth and 7 months

- Physical characteristics: Newborns have no control of their bodies, after the sixth month they start crawling. At this stage, electrical shocks and swallowing small objects are very risky. In the crib, pinched fingers and limbs, and suffocation with blankets and pillows are common accidents.

7 to 12months

- Physical characteristics: Babies start to walk, try to get away from the crib and climb gates. Is the time when children try to climb everywhere and poke their noses into everything. From the age of one, children usually start babbling and become aware of some actions.

Common accidents:

- Falls (high chair and climbing accidents)
- Choking: with toys and small objects and food
- Strangulation by cords and strings (usually from toys, clothes or curtains)
- Asphyxia
- Burns (shower, feeding bottle, cigarettes, coffee, electrical cords and outlets…)
- Drowning

1 to 2 years:

- Physical characteristics: Now is the time when children get to know the world by repeating things. The children have already a good coordination and can easily go wherever they want. At this stage they will explore the home and the garden. It is therefore important to keep hazardous products out of range and kitchen doors closed and locked as children are now able to go to all rooms in the home and might find cleaning products and drugs.

Common accidents:

- Asphyxia
- Intoxication

- Falls
- Burns (shower, feeding bottle…)
- Drowning
- Electric shock
- Inhalation of substances or foreign bodies
- Being run over by cars
- Pricks and bites

3 to 4 years

- Physical characteristics: At this age children have already a more perceptive capacity based usually on symbols. This is the time when cartoons can be seen as real, and when they try everything they see.

Common accidents:

- Falls and traumatisms
- Accidents with pedestrians and vehicles
- Accidents with bikes and tricycles
- Burns
- Bites from animals
- Drowning
- Poisoning

5 to 9 years

- Physical characteristics: From the age of five, children are absorbing a lot more detailed and specific information and they are also able to put it into a context and make logical links about the implications of what they do and how they do it. They will probably also be able to take some reassurance from the fact that they will remember what you discuss with them and act on it [Wash 1993].

At this age, children are more likely to imitate adults' behavior. Matches and lighters, scissors, kitchen appliances, irons, kettles and machinery should therefore be kept out of children's reach.

Common accidents:

- Traffic accidents with pedestrians and vehicles
- Falls and traumas
- Burns
- Bites from animals
- Drowning
- Poisoning

2.1.5 Accidents and environment

Young children learn through interaction with their physical, social and cultural environments. Play is the integrative process which facilitates their learning and interaction.

Play promotes young children's physical, emotional, social and intellectual development. Children's play environments should be designed for a healthy and safe development. D. Y. Rospa says: "We need to see exciting and stimulating play environments with high play value. These will contribute to the physical and psychological development of the child and discourage children from playing in dangerous places such as railway lines, river banks, alongside roads, kitchens and parking spaces".

The nature, quality and conditions of children's physical environments provide the conditions to explore and learn. The environment can stimulate curiosity, imagination, creativity, but also involves the possibility of accidents, owing to each child's individual capacity and need to experiment.

Studies confirmed that a limited and poorly organized space disturbs the child and the interactions adult - child, child - environment and adult - environment, leading to a considerable increase in accident risk and home hazards.

The interaction of children and environment changes as children grow at all development stages, however, a proportional relation between children's need of experimentation (interaction with the environment) and the number of accidents has been proved.

In the first years of life, children's immediate environment is mostly their homes, and again, that is where over 80% of the accidents happen. Since their homes are their immediate and only environment, mainly in the first years of life, residential architecture and construction appear as health and safety determinants.

2.1.6 Types of accidents

In the first years of life, children spend most of their time at home. As they grow, the way they interact with the environment which they live in changes. This interaction becomes more pronounced as children grow, but they develop a sense of danger only after reaching the age of five.

According to the European Child Safety Alliance, children between 0 and 4 years old are the most affected group in home accidents. The mortality database between 1996 and 2000 pointed out the leading causes of injury death of children in the EU:

- 30% unspecified unintentional injuries
- 21% motor vehicles
- 15% drowning
- 9% violence
- 7% external causes
- 6% falls

There are several consequences of those accidents: smaller injuries, permanent disabilities, hospital stay, development delays. Most of the accidents happen during play or leisure activities (32%), as shown in figure 6.

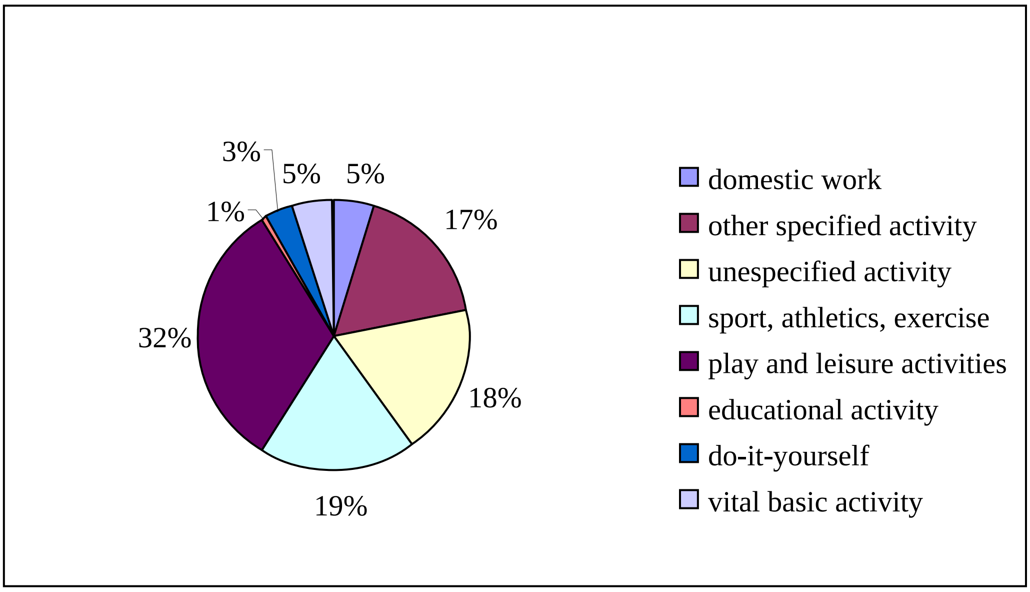


Figure 6: Activity at the time of Injury [IDB 2002-2004]

Figure 7 shows the activity at the time of injury by age. For children between 0 and 4, play and leisure were the main activities at the time of injury. This rate increases with children ages 5 to 14.

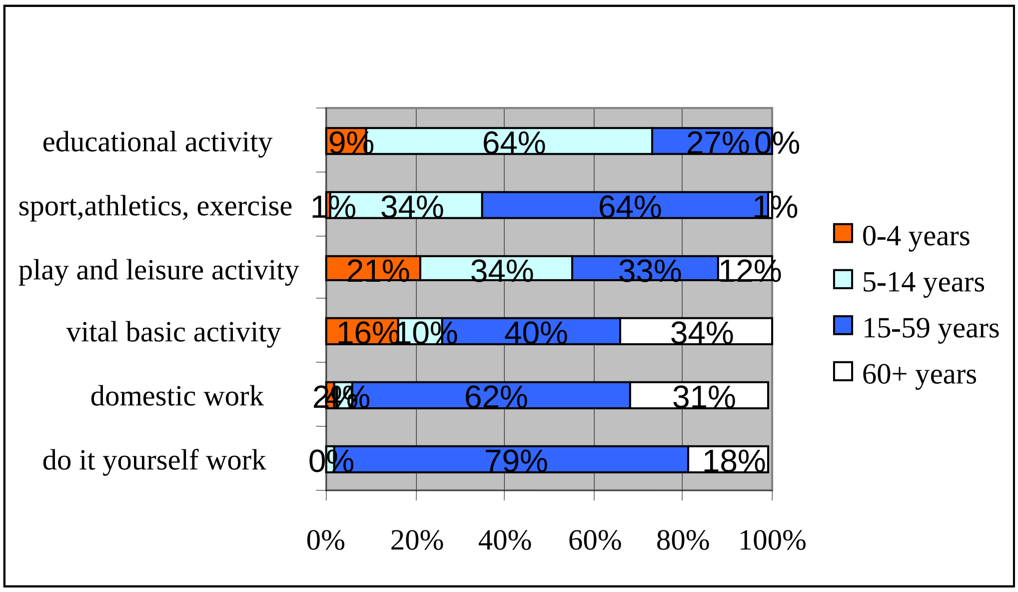


Figure 7: Activity at the time of Injury by Age [IDB 2002-2004]

According to a study conducted by IDB between 2002 and 2004 [Injuries 2006], the most frequent accident mechanisms during play and leisure activity are:

1. Falls 53%
2. Collisions 20%
3. Crushing, cutting 12%

Figure 8 gives an overview of the injury mechanism during play and leisure activity.

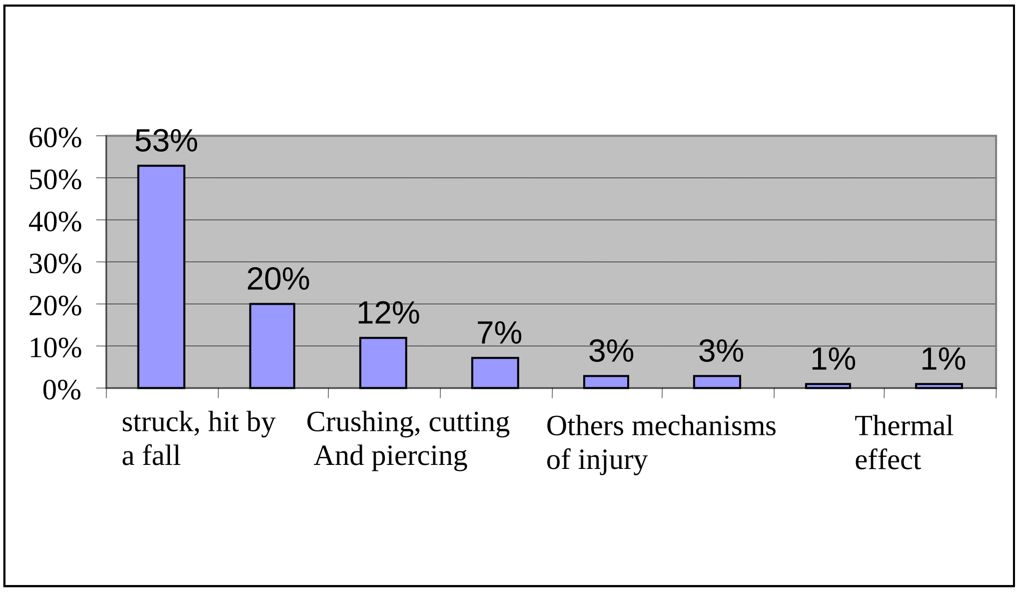


Figure 8: Play and Leisure Activity and Injury Mechanism [IDB 2002-2004]

2.1.6.1 Drowning

Drowning is caused by the interruption of the body's absorption of oxygen from air leading to asphyxia. It happens when the lungs fill with liquid (often water). The rate of drowning world-wide varies according to the access of water and swimming culture. For example, in the UK the drowning rate is 1 /150 000 population, while in the USA the rate is around 1 / 50 000 population.

Drowning is a frequent cause of injury and death in all ages.

Prevention:

- Teach children how to swim
- Never leave a free access to swimming pools
- Never leave bathtubs and buckets full of water
- Never leave children unattended while bathing
- Use specific bathing equipment for small children
- Use anti-slippery devices in the bathroom

2.1.6.2 Fall

Falls are caused by the unstable gait of toddlers, the presence of objects on the floor, lack of supervision, curiosity of the child, product failures, stairs and climbs on furniture. Children between the age of 0 to 5 are the most affected group together with the elderly over 70 years of age. Concerning children, windows pose a risk and have a huge curiosity factor.

Prevention:

- Keep floors free of toys and obstructions
- Closer supervision
- Never leave babies unattended on raised surfaces
- Keep floors dry
- Always ensure the bed-rail of the baby cot is raised when the baby is in the cot
- Windows and doors must be locked to avoid misadventure by children
- Avoid placing stepping stones such as chairs and furniture next to a window
- Avoid side-turning of a baby chair
- Keep stairs free of clutter and use stair gate
- Stairs should be made out of bounds for playing
- Use childproof windows locks – for children over 5 years, too
- Pay attention to glass doors and windows, children may run through them

2.1.6.3 Choking

Choking is caused by accidental swallowing of a foreign body, covering of the head by blankets, strangulation, and accidental suffocation by a pillow while the baby sleeps.

Prevention:

- Choose appropriate toys according to age
- Ensure small objects are out of children’s reach
- Pull cords on curtains and blinds should be short and be kept out of reach of children
- Foldable furniture should be properly placed and locked
- Strings and plastic bags should be kept out of reach
- Monitoring during sleep, no blanket over the baby's face, no pillows until 1 year old

2.1.6.4 Burns and scalds

Burns and scalds are usually caused by hot water, fire and contact with hot objects (cooking utensils)

Prevention:

- Ensure a proper fence or door is installed at the entrance of the kitchen and keep it closed at all times
- While cooking pay attention to the stove fire and the cooking utensils, turn the pan handle away from the front to the wall
- Always test the water temperature before a bath
- All hot objects, including irons or containers with hot matter must not be placed near the edge of the table. Avoid using tablecloths. Keep matches and lighters out of reach
- Use outlet covers
- Warn children against playing with fire

- Install a smoke detector

2.1.6.5 Poisoning

Poisoning can be caused by accidental swallowing of drugs, detergents, insecticides and other substances. With small children, food poisoning and swallowing of drugs should be particularly paid attention to.

Prevention:

- Keep medicines and chemicals out of sight and reach of children
- Always store chemicals in their original containers with appropriate labels.
- Drugs (medicines) should be locked away
- Toys and products should meet international standards, e.g. coloring materials should be non-toxic

2.1.6.6 Electricity

Statistics show the number of electricity incidents in US homes caused each year:
300 electrocutions
12 000 shock and burn injuries
150 000 fires [NSC, CPSC, OSHA 2007]

Prevention:

- Grounding: Install a ground wire. In case of a short circuit, electricity should flow through the grounding system instead of a person
- Ground fault circuit interrupters: If there is an imbalance in the energy flow this device will cut the power to prevent serious injuries. It should be used in bathrooms, garages, near kitchen sinks and outdoors. It is a simple device that can be found in some outlets.

- Keep appliances such as hairdryers away from bathtubs, puddles, sinks, and wet hands.
- Children’s natural curiosity can lead to electrical accidents. Therefore keep appliances and cords away from children, bathtubs and sinks. Use safety plugs.
- Electricity can travel down the strings of a kite or balloons that hit power lines, possibly causing fire and shocks. Keep metallic balloons indoors, as they are highly conductive.
- Pay attention to “Danger – high voltage” signs
- Pay attention to wires – report any downed, hanging or burning wires to the fire department.
- All electrical devices for the swimming pool must be grounded properly.
- Don’t have any plug-in appliances near the pool
- Rugs should have a non-skid back

2.1.6.7 Products and building elements involved in accidents

Table 1 contains a statistics realized by the International Databank (IDB) listing the main products involved in accidents.

Table 1: **Products Involved in Accidents - IDB, 2000-2004, Greece.**

Product causing the accident	Total	Percent	Admitted percent	MLS*
floors indoors	6067	14.8	15.11	9
stairs	2813	6.8	6.29	2
furniture	2076	5	3.76	2
human being	2072	5	2.12	2
part of the building	1136	2.8	5.19	1
door of the building	950	2.3	3.16	2
cutlery, kitchen utensils	545	1.4	2.2	1.5
sanitary equipments	534	1.4	6.37	1.5
household machines	211	0.5	3.79	2
ladder	83	0.2	6.02	5
non-fixtures	80	0.2	2.5	1.5
pharmaceutical products	79	0.2	96.2	2
personal care, hygiene	69	0.2	1.45	1
clothing and accessories	30	0.1	3.33	3
weapons	25	0.1	20	4
baby/child furniture	24	0.1	8.33	2.25
soap/polish and detergent	20	0.1	50	1
baby care equipment	11	0	9.09	1
Unspecified	198	0.5	13.13	2
heating equipment	67	0.2	0	

*IDB 2000-2004 - *MLS: median length of stay in hospital*

The evaluation of the products and building parts involved in the accidents is one of the objectives of this work.

2.2 INITIATIVES WORLD-WIDE

Drowning is the leading cause of death in children ages 1-4 years in low to middle income countries of the European Union. Road traffic injuries are the leading cause in the age group of 5 – 14 years in high income countries. Children from the most deprived social classes suffer from a 3-4 times higher mortality. Death is the worst consequence, long term physical and psychological disabilities are the major consequences.

In the field of home accidents there is still the need for a better surveillance to make the problem and the risks more visible. The prevention in the home needs to be a part of the overall injury prevention plans with involvement of multiple sectors. There is a need to demonstrate that there is evidence of the effectiveness that injuries in the home are preventable by legislation, home visitation, child-proof closures, safer home environments (use of windows bars, guards, stair gates, smoke alarms, and thermostats on water heaters) [Sethi 2005].

The World Health Organization is helping governments to provide data systems and programs to prevent accidents and improve the negative statistics. Systems such as EHLASS, IDB; LARES, ECOHEIS, ENHIS and CEHAP record data about accidents and raise awareness of domestic injuries.

Some of those programs will be described below with the intention of underscoring the need of integration between all professionals and governments that are involved in children’s health, environment and products. The aim is not only to justify this paper, but to work out the points where architecture, construction codes and building standards could help.

2.2.1 Austria

In Austria, deaths of 0 to 19 year olds due to home injuries makes up 14% of all injury deaths, 45% of hospital admissions and 43% of emergency department visits for accidents are due to home injuries.

The Austrian Institute for Home and Leisure Safety – Institut Sicher Leben – has established the Austrian Program for the prevention of Unintentional Injuries. This program started in 2006 and will end in December 2010. It intends to call on various sectors to collaborate in the fight against accidents rates.

Some of the political measures aimed at a national level by the Program are:

- Systematic collection of home and leisure injury statistics within national statistics, (collecting data)

- Mandating home and leisure injury prevention in university courses, (for example: TU WIEN : Universal Design Course)

- The improvement of building standards (The “Build for all” Program)

- **Strategies of the Program:**

- Increasing the security of the environment: “Technical measures to prevent danger or to ensure personal protection are generally the most reliable ones. Where such possibilities exist, they should be used as a matter of routine. If required and acceptable, direct legal standards should also be created”, declared Mrs. Mathilde Sector from the Austrian Injury Prevention Plan.

- Improvement of the qualification of relevant professional groups:

- Members of professions which could make a particular contribution to accident prevention – for example by advising patients, clients, designers or customers – should be in the position to fulfill these duties expertly and efficiently. The necessary knowledge should be communicated by default in the professional training plans and further training courses [Sector 2005].

- Planning, coordination and evaluation: Decision-makers on all levels in all sectors should be conscious of how they can contribute to the reduction of health risks due to accidents. Accident prevention should become a joint concern of the responsible state and private organisations. Broad cooperation should therefore be facilitated [Sector 2005].

Measures of the Program:

- Increasing the security of the surroundings:

Increase of the user safety of the buildings: Following an agreement according to §15a of the Austrian Constitution, uniform technical guidelines, which take particularly consider aspects of user safety for all age groups and the disabled and sick, will be formulated for construction laws throughout Austria. A series of safety-relevant provisions are currently not or inconsistently codified into Austrian construction laws (grabs, bars, handrails, marking of stairs, illumination, window locks, fire prevention equipment, etc.) All efficient and economically feasible technical measures for the increase of security of residents should be prescribed. In this connection, special consideration must be given to the needs of vulnerable population groups (children, seniors, and the disabled).

- Encouragement of barrier-free construction:

Barrier-free and senior-appropriate construction should also be encouraged in private construction through effective measures. Maximum financial support should only be given if guidelines for barrier-free and senior-friendly construction are adhered to especially low-barrier access to the building and to the most important living space, spatial opportunity for retrofitting a lift or stair lift, passage width of least 80cm for doors, sufficiently large toilets and bathrooms.

- Low-barrier design of footpaths:

"The expansion and renovation of footpaths should be encouraged. The long-term goal is to make footpaths free of stumbling blocks so that they correspond to the special needs of the disabled and elderly people. All residences in rural areas should have continuous access via a connection to the footpath network. Those who work on behalf of seniors' interests should be consulted during street construction projects."

- Optimization and execution of the product safety laws:

In particular, the risk evaluation of products and services should be systematized with the goal of making authorities intervene not just in complaints, but also to reduce injury frequencies. It should be checked where, by combining different administrative offices in a federal agency; the efficiency with which the law is executed can be increased [Sector 2005].

- Expansion of consumer representation in the composition of standards:

The standards for consumer products are often formulated exclusively by the producers. The view of the consumer and those of safety research are thus frequently not sufficiently considered. It should be ensured that consumer representatives and safety researchers participate in the standardizing process in order to bring in safety viewpoints [Sector 2005].

- Specific technical measures:

´Some known dangers which continuously cause fatal accidents can be eliminated with specific regulation. For example, artificial bodies of water in the private sector (pools) should be secured such that small children without supervision have no access to them.

Improved product standards prevent the strangulation of children for example. For existing lift facilities, the after-the–fact installation of lift cage doors is encouraged and up to a particular deadline legally prescribed´ [WHO 2005]

Figure 9 shows that sometimes the lack of safety information is not the real problem. Usually in developed countries, in middle and upper classes, knowledge about safety equipment is considerable, still there is a big step between knowing and prevention or using the equipment adequately. The comparison between children car restraint systems and the other safety devices proves once more how prevention programs help (there is a difference of about 65% regarding the used by the consumers).

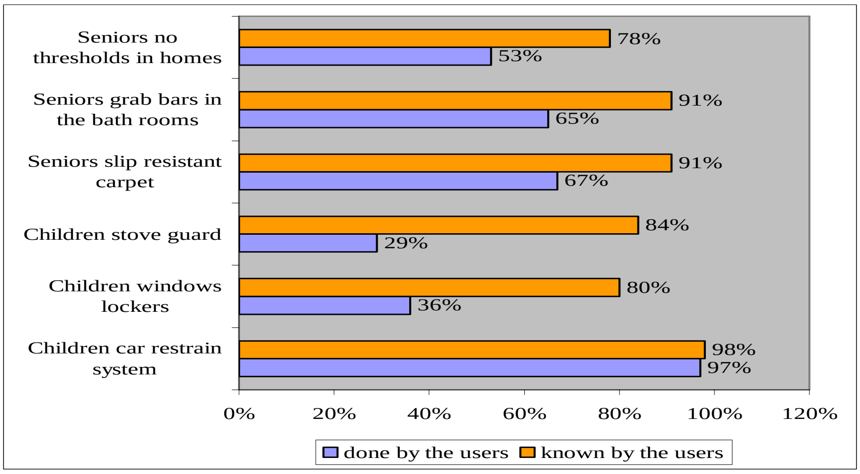


Figure 9: Knowledge and Implementation of some Safety Recommendations [KFV 2004]

Another point worth noting is that much more safety devices have been developed for elderly people than for children.

2.2.2 Germany

In Germany, about 34% of the deaths are caused by motor vehicle accidents, 21% by other unintentional injuries, 13% by drowning, 5% by fall, 4% by fires and 2% are due to poisoning. Injuries are the third main cause of death in the region, right after cardiovascular diseases and cancer. In spite of their magnitude and preventability, injuries receive far less attention than other diseases.

The German Federal Statistical Office Survey (2003) for fatal home and road traffic accidents shows that home accidents represent the biggest percentage of accidents in the age groups of children below 5 years and of the elderly over 70 years.

The last survey on home and leisure accidents by BAUA found that home injuries accounted for 256,000 cases, which represents 45% of all injuries in one year. Details were collected on the victims and the accident location, cause, mechanism, and activity. The study reported a small decrease in the rate of fatal accidents, but on the other hand, there was a remarkable increase in severe injuries among infants (<1year) and toddlers (1 to 5 years).

In 2002, a total of 210,000 children (under 15) were seriously injured in Germany alone. The BAUA survey offers indications about the location of the accidents and about the products and the environmental characteristics involved in the accident, revealing that most of the home accidents in Germany occurred in the living room, followed by the garden, the yard and the kitchen.

Regarding the exact causes of falls, the Delmenhorst Injury Monitoring – coordinated by Dr Gabriele Ellsäßer in Germany – gives details about dwelling/ building related items: 18.3% of the accidents were caused by the dwelling characteristics: 9.2% stairs, 2.9% doors, 2.7% floor covering, 1.6% radiators, 0.9% windows and 1% others. On the other hand, 19.1% of the falls had been related to furniture [WHO 2005].

2.2.3 Denmark

A Children's Fatal Accident Registry was recently developed by the National Institute of Public Health, covering 800 fatal home/leisure accidents in children between 0 and 14 years, from 1975 to 2000, based on death certificates. A detailed description of accidents was provided, together with detailed coding of place, mechanism, activity and involved products.

Mechanisms of injury, place and activity were coded at 1-digit level (place = residential areas, mechanism = fall, activity = play and leisure activity). The information can be linked to other registers, primarily those of the Statistics Denmark. Registers from the Statistics Denmark include data from approximately 1980 onwards:
Data included in the survey:

- Family type: biological and social parents, number and age of the children living with the family, municipality and country, and changes of address.
- Dwelling: type (terrace, detached, block, nº of floors), toilets, bathroom, kitchen, heating system, area, owner (private, co-operative), water supply and drain, year of construction, external wall material, roofing.
- Social characteristics of the parents: social class based on profession, highest education, country of origin, income.
- The geographical place of residence is broken down into squares of 100 x 100 meters to identify any local clusters of accidents.
- Product or furniture involved in the accident
- Number of accidents occurring in bathrooms or staircases
- Products involved in poisoning or suffocation
- Relation between mother's education and risks of accidents
- Differences between fire risks in blocks and detached houses

2.2.4 Italy

The ISTAT conducts a periodical survey of family life habits. A sample of around 53,000 subjects (23,000 Italian families) was interviewed in emergency rooms and hospitals, showing that 2.848.000 persons were injured at home, which represents about 5% of the population or an incidence of 50 cases per 1000 inhabitants per year. Population groups that spend more time at home were more affected: women 68/1000 inhabitants per year vs. men 30.4/1000 inhabitants. Children at pre-school age have an incidence rate of 62.4/1000.

With a home injuries evolution monitoring and the formulation of prevention programs in mind, the Italian government designed a 3-level information system which includes:

- Surveillance of emergency departments' attendance due to home accidents from a large sample of hospitals;
- Extraction of domestic trauma hospital discharge records from the National Hospital Register;
- Extraction of home injury death cases from the National Mortality Register

Once specific risk groups or events of particular relevance are identified, analytical studies will be applied to small samples according to representatives of the groups, with an aim to investigate the accident determinants and risk levels.

2.2.5 Lithuania

Latvia, Estonia and Lithuania have the highest child injury mortality rates in the EU. Injuries are the third cause of death in Lithuania. Every year approximately 5000 people, including 400 children and adolescents, die from injuries. In 2003 nearly 75,000 children were injured and the injury rate rose to 119.6/1000 population, meaning over 11%.

In the face of the statistics, a study was developed in Klaipeda (third largest city in Lithuania with a population of about 200,000). In 1999, a total of 2027 emergencies with child injuries were recorded at the Klaipeda Children's Hospital; domestic injuries were responsible for 77.2% of all child injuries, 64.5% of those affected were boys and 35.5% girls.

The hospital reports classified injuries according to the affected part of the body: upper extremities 51.3%, lower extremities 30.6%, head and neck 11.5%, torso 2.5%, multiple injuries 0.5% , unknown 3.4%. Most injuries occurred when children were alone at home. Preventive programs have been developed in Lithuania with the help of the Swedish government.

2.2.6 United Kingdom

The Housing Act 2004 has introduced a new way for local authorities to assess housing conditions in England and Wales. The HHSRS – Housing Health and Safety Rating System – was developed by the British government in March 2001. The past models didn't give indicators about the degree of failures and hazards inside dwellings.

"The aim of the HHSRS is to grade the severity of threats in the home, to be hazard focused, to be comprehensive and to be evidence based", said Prof D. Ormnady. The program is supported by the Building Regulation, Health and Safety Departments. HHSRS covers all potential health risks and unavoidable – likelihood of an accidents to happen and potential its harm and its threats to safety, the aim is to reduce the risks to minimum.

The HHRSR addresses all the key issues that affect health and safety, it provides an analysis of how hazardous a property is and includes evidence and statistical information to assist inspectors in making their judgments.

The UK has produced several housing and population databases which have been used for building up an effective rating system. Data on the health outcome are available through various institutions such as: the Home Accidents Surveillance System, the British Crime Survey, the Fire Brigades Statistics, the Hospital Episode Statistics, the GP research database and the mortality data.

The database provides information on the type and severity of the injury, the product or dwelling feature involved, the age etc. of the victim, information on burglary and attempted burglary, causes of death and site of the death. Matching data gives a national average likelihood of an occurrence which could cause harm and give a national average spread of outcomes from such an occurrence. [...] The main principle underlying the HHSRS is that a dwelling should provide a safe and healthy environment for any potential occupant and visitor. The final aim of the system adopted by the legislation is to direct actions to improve the housing stock [Ormnady 2005]

How the program works:
The HHSRS puts hazards in four groups, reflecting the basic health requirements:

- Physiological requirements
- Psychological requirements
- Protection against infection
- Protection against accidents, including falls, electric shocks, burns, scalds and fires, collisions, cuts and strains

A numeric score is generated by a trained surveyor who inspects dwellings. The information observed during the inspection should be properly and accurately recorded as this will provide evidence to justify and support the judgments which result in the numerical Hazard Score. The rating system requires two surveyor’s judgments for each hazard.

There is an assessment of:

- The likelihood, over the next 12 months, of an occurrence that could result in harm to a member of the vulnerable age group
- The range of potential outcomes from such an occurrence
- It allows differentiation between similar hazards for which the likelihood may be the same, but the outcome is very different
- Using the two judgments, the HHSRS formula is used to generate the numerical Hazard Score for each of the hazards. Three sets of figures are used to generate a Hazard Score, which are:
- A weighting for each class of harm, reflecting the degree of incapacity to the victim resulting from the occurrence. Given the same likelihood, hazards which

cannot result in death will not produce a score as high as those which may cause death (risks from poor ergonomics vs. risks from carbon monoxide)

- The likelihood of an occurrence involving a member of a vulnerable age group, expressed as a ratio
- The spread of possible harms resulting from an occurrence, expressed by percentage for each of the four classes of harm.

The Hazard Score is calculated as the sum of the products of the weightings for each class of harm, which could result from the particular hazard, multiplied by the likelihood of an occurrence, and multiplied by the set of percentages showing the spread of harms.

In March 2001, the HHSRS proposed a list of hazards which constantly appeared in home accidents. The list below shows again that hazards are easily recognizable, but the building elements involved are not cited.

- hazards associated with excessive indoor temperatures, including excessive cold and high temperatures
- fall hazards including stairs, steps or ramps, falls on the level, falls between levels, falls involving windows or from balconies and landings, and falls associated with baths
- hazards from fire
- hazards associated with hot surfaces and materials
- hazards associated with dampness and mould growth
- hazards from carbon monoxide
- hazards from radiation
- electrical hazards
- hazards from noise, lead and from asbestos
- hazards from design, construction and maintenance
- hazards from inadequate provision for food safety
- hazards associated with inadequate provision for maintaining hygiene
- hazards associated with inadequate sanitation or drainage

- hazards from structural failure
- hazards from inadequate lighting
- hazards from uncombusted fuel gas
- entrapment and collision hazards
- hazards from poor ergonomics

Interesting numbers:
More than 38,000 children are injured seriously enough on UK playgrounds each year to be taken to the hospital. That compares to around 30,000 children who are killed and injured on British roads. But this number is still tiny compared to the 880,000 children who are hurt in accidents in the home every year [Royal Society for the Prevention of Accidents]

2.2.7 USA

Data on child injuries are provided by the NEISS, NVSS, NAMCS, NHAMCS and NHIS. Data on domestic hazards are stored by the HUD, ICARIS and the US Consumer Product Safety Commission.

In the US, falls are the leading cause of unintentional injuries treated in emergency departments. In the age groups from 1 to 9 years, most of the falls occurred at home [NAMCS 2000].

Analyses conducted by NCIPC include a profile of falls at home. NEISS data from 2001-2002 show that over 1.5 million children aged 0-9 were treated in US emergency departments because of injuries caused by falls at home, many of them occurring on stairs.

When the location of the accident is registered, very often information is given on the room where the accident occurred, but not which element in the room caused the accident.

Some US states have sophisticated building codes to prevent residential accidents. Examples are Florida, Massachusetts and New York. They all provide for safety devices both on houses and on public buildings, although the main focus is still on elderly people.

2.2.8 France

For children from 0 to 4 years the interior of the home (especially the kitchen, the bedroom and the bathroom) represents the likely place for an accident to happen (more than 80%). With increasing age, the number of accidents declines and accidents occur more frequently outside the home.

The Permanent Study on Home and Leisure Injuries (EPAQ) represents the French part of the European Home and Leisure Injury Surveillance System (EHLASS). This study does not allow an overview of the data on home and leisure injuries in France, as it is limited to ten hospitals and records only home and leisure injuries linked to emergency treatments.

2.2.9 IDB – International Database

"Historically, the focus of injury prevention in Europe was first on work place safety, then traffic safety and has been recently shifted towards accidents during leisure time and at home, originating from the interest in the safety of consumer products in the Common Market. In fact, over 70% of all unintentional injuries are supposed to happen in the ´home and leisure´ domain. More than half of those accidents occur inside residential areas.

Regarding smaller children, the rate of home accident is even higher. Only in 2000, the central database IDB for the data collected in the Member States under the EHASS was set up by the Directorate General for Public Health and Consumer Protection of the European Commission [Bauer, 2000]

- How does IDB work?

Using a standard protocol, data is collected from hospital emergency departments of EU member states. Until now, the 15 original EU members have considerably progressed in their database. In the Public Health Program 2002-2008, IDB implementation efforts are oriented towards the new member states.

The objective of the current IDB is to provide information about the external causes and circumstances in the area of home and leisure injuries for research and prevention at EU level. In the near future it should be expanded to all types of injuries.

The analysis of the detailed place where the accident occurred in combination with other relevant data (elements like activity, mechanism, injury severity, relation to product and accident description) is very likely to give valuable insights into domestic accidents and is described in table 2.

Table 2: Analysis of Children´s Home Injuries that were treated in Hospitals

Place of occurrence: residential area	**by**	**Further data elements for analysis**
Kitchen		activity and related products
Living room , bedroom		Mechanism
bathroom, washroom		product causing injury
stairs, indoors		product involved in accident
residence indoors, others		type of injury, injured body part
residence, outdoor		type of treatment
playground at home		accident description
Garden		Mechanism

IDB 2000

2.2.10 EHLASS- European Home and Leisure Accident Surveillance System

It was originally designed to improve product safety by monitoring accidental injuries related to consumer products in Europe. A Preventive Product Safety Analysis was conducted by safety experts from France, Greece, the Netherlands, Sweden and Austria. The EHLASS proposed a "product safety priority table" which was applied to data sets and yielded the following top ten "priority product categories" as shown in table 3.

Table 3: Priority Product Categories - Rank 1 to 24: 1= highest, rank 24= lowest

Product category	**Frequency rank**	**Severity rank**	**Product causality rank**	**Average rank**
Other and unspecified products	1	3	17	7
Electric equipment primary for use in household	6	14	2	7
Human beings, animals, animal articles	5	10	13	9
Part of buildings and stationary furniture	3	7	18	9
Food, beverage , tobacco	14	11	4	10
Chemicals, detergents, pharmaceutical products	16	4	10	10
Stationary equipment, processed and natural surfaces – outside	2	8	20	10
Medico-technical equipment, laboratory equipment	23	6	1	10
Natural elements, plants and trees	15	9	8	11
Domestic appliances and equipment	12	15	6	11

2.3 BUILDING REGULATION AND DESIGN ISSUES

2.3.1 An overview of building code to avoid accidents

This part of the research shows some of the main existing regulations and building codes to prevent child accidents. The intention is to point out how children are perceived by governments and by the building industry when it comes to drafting regulations.

2.3.1.1 Fall-related accidents

Falls are the most common unintentional injuries. In the United States alone, over 9 million people are taken to hospital emergency units, and more than 140 children up to 14 years die per year in the US as consequence of falls.

This situation posed a great challenge to the government which responded by introducing new safety measures to avoid this type of accidents.

The statistics show that there is a strong relation between fall accidents and parents' educational level and the location of the residence. A strong relation was established between the neighborhood and the rate of falls from heights. In certain neighborhoods where most of the houses are multi-story buildings and households have lower incomes, the rate of accidents was up to 20% compared to 4% in other neighborhoods.

Another interesting fact is that most of the fall-related injuries involve falls from first or second floors, mainly in summer time when parents allow children to play on balconies, near fire escapes and open windows. Fractures are the most common injuries resulting from fall-related accidents.

According to the American Academy of Pediatrics, “Considerable success has been reported with modification of the physical environment. Spacing of railings determines how well they function to prevent falls from balconies, decks, porches, and bleachers. Widely spaced rails are ineffective barriers because they permit a child's body to slip through.”

“Theoretically all children younger than 6 years can slip through a 6-inches opening, and none older than 1 year can pass through a 4-inches (vertical bars, not horizontal) opening. Because of that, the 4 in. spacing was adopted by all three of the regional building code organizations in the United States. Most codes specify railing heights of 36 in.“

"An example that prevention programs help is the law for window guards adopted in New York in 1976. This legislation said that every apartment where children under 10 years old lived in must have window guards on every window. With this simple code, a decrease of circa 35% of the accidents was related, and no accident was reported in houses where the guarded windows were properly used. The problem of this legislation is the concern about fire escapes. According to the American National Fire Brigade, the use of window guards can make fire escapes in an emergency situation harder. That’s why the use of it did not become obligatory.”

Other technologies such as L-shaped window locks, security nets, and opening locks are currently in use, but no other legislation was adopted so far and considered safe in all aspects.

The American Academy of Pediatrics issued a guideline to prevent fall-related accidents which includes:

- Install locks on windows.
- Do not use egress bigger than 4 inches in openings.
- Open double-hung windows from the top only.

- Fixed guards, commonly used to prevent intrusion, should not be used, because they may prevent egress in the case of fire.
- Install operable window guards on second- and higher-story windows (unless prohibited by local fire regulations).
- Window screens are designed to keep insects out, but because they are not strong enough to keep children inside, they will not prevent falls from windows.
- Discourage or prohibit children from playing on fire escapes, roofs, and balconies, especially those that are not adequately fenced with vertical bars that have openings of 10 cm or less. Encourage the use of safe ground-level play areas, such as public parks and playgrounds. Ideally, these areas have been inspected and found safe by a nationally certified playground inspector.
- Avoid placing furniture, on which children may climb, near windows or on balconies.

Pediatricians, together with the building industry, should support community-wide programs to encourage the use of window guards and other safety elements to avoid fall-related accidents. Public health authorities, in conjunction with fire prevention officials, should guide such programs so that regulations may be based on concerns about both fire safety and fall prevention (accident prevention).

Designers and manufacturers of windows and window guards must be encouraged to develop and make more widely available additional products that can prevent falls and allow egress in case of fire. Examples are windows that cannot be pushed out or up by a child and window guards with safety catches that can be operated only by adults.

Legislation should be introduced that requires landlords to install releasable window guards or window barriers above the ground floor in multiple-story dwellings where children live.

Building codes should ensure that balconies, decks, porches, bleachers, roofs, and fire escapes have railings with vertical openings no larger than 10 cm.

Local communities and recreation departments should develop strategies to prohibit playing areas in dangerously high places. Such strategies might include the expansion of safe public playground activities, including child care and recreational programs, as well as attempts to make public areas safer for children.

Whenever possible, grass or shrubbery should be planted at the bases of tall buildings to soften the impact surface [Committee on Injury and Poison Prevention 2001].

Florida's building code includes some interesting rules to prevent fall-related accidents: Stair treads and risers shall be of uniform size and shape. The tolerance between the largest and the smallest riser or between the largest and smallest tread shall not exceed 9.5 mm in any flight of stairs.

There must be a floor or landing at the bottom and top of each stairway. The width of landings shall not be less than the width of the stairway they serve. Every landing shall have a minimum dimension measured in direction of travel equal to the width of the stairway. Such dimension must not exceed 121.9 cm where the stairway has a straight run.

2.3.1.2 Swimming pool-related accidents

According to the American Consumer Product Safety Commission, every year in the United States over 350 children under 5 years old drown in residential swimming pools, spas and bath tubs. The State of Massachusetts Building Code requires that swimming pools with depths over 24 inches be attributed a higher accident potential within the Code, meaning that barriers, fencing, latching and alarms are obligatory. According to the Building Code, the top of the barrier should not be less than 48 inches above grade and should not start over 10 cm above ground.

According to the Florida Building Code (chapter 4), there are special and detailed requirements based on the use and occupancy of swimming pools:

- „ all doors and windows providing direct access from the house to the pool shall be equipped with an exit alarm [...] The alarm shall produce a continuous audible warning when the door and its screen are opened. The alarm shall sound straight after the door is opened and be capable of being heard through the whole house during normal household activities [...]"

2.3.2 Building regulation in public spaces vs. private environments

A relatively low number of child accidents occurs in public buildings, since over 80% of those accidents happen in private dwellings. This shows that prevention practices in public buildings could be useful for new building codes regulating private homes.

Swimming pools:
The International Building Code 2003 specifies:
"For public swimming pools: All public swimming pools shall be completely enclosed by a fence at least 129.0 cm in height or a screen enclosure. Openings in the fence shall not exceed 10.2 cm of diameter sphere. The fence or enclosure shall be equipped with self-closing and self-latching gates."

"For residential swimming pools: When there is a barrier, it should be at least 1219 mm high."

The analysis of existing safety regulations has shown a discrepancy between the public and the private sphere. Regulation targeting reduction of injuries is very often valid only for public institutions (pool fencing).

2.3.3 Other building regulations and standards

The European Child Safety Alliance suggests their main regulations and standards for product, equipment and building elements in a document entitled “A Guide to Child Safety Regulation & Standards in Europe”. These regulations and standards are listed according to main accident mechanism, which are drowning, falls, burns, poisoning, chocking and suffocation, and include examples f best practice in Europe.

3 METHODOLOGY

This work primarily intends to create a risk assessment design guideline, classifying building elements (including related objects) into risk levels, according to the hazards present inside residences. It also suggests design solutions to prevent accidents in children between 0 and 4 years old in residences.

The risk assessment design guideline is to be used to identify potential hazards in children's residential environment and give directions to architects, professional of the building industry and parents as to identify and avoid hazards and to subsequently reduce the number child accidents.
Finally, the guideline suggests the inclusion of safety aspects in children's direct environment by proposing design ideas and relevant technologies. One case study is presented in section 4.5.1.

First of all, all building elements inside every room type in the residence and their hazards have to be listed, pointing out the location of and the building elements involved in the accidents.

For the risk assessment guideline a specific methodology was used, as described below in section 3.1. It is important to notice that the design guideline risk classification matrix is divided in three columns, each one carrying the same weight.

After that, a list of issues is given that architects or the building industry could tackle. The final objective is to present a risk assessment design guideline and suggest solutions to a safer design that could one day become part of building standards for architects and constructors, or at least could create a valid room type risk classification for relevant analyses.

Main Objectives:

- Recognize potential hazards to children in dwellings in each room type;

- Classify hazards by risk level, including three categories: weighting the likelihood of the mechanism of injury (associated to each hazard), their consequences to the child (impacts on child development) and the possibility of identification and fixing it;
- A final risk is associated to each hazard through the matrix;
- Creating of a final list of potential design problems, and finding design solutions that eliminate or reduce hazards; to give some technology suggestion in the form of a design guideline.

Table 4: Methodology objectives and approaches

Objective	Approach
Identification of potential hazards by room type and association of an injury mechanism to each hazard	Review of existing literature and available data
Evaluation scheme for risk assessment	Use of a check-list format, use of FMEA methodology
Risk evaluation matrix of hazards	Application of a two-dimensional matrix involving a) accident´s likelihood by mechanism of injury , b) consequences to the child, c) Identification and possibility of fixing design problems. Attributing a final risk assessment number to each hazard.
Risk evaluation - identification of main design problems	Analysis of the result of the risk evaluation matrix.
Identification of design solutions and possible technology for accident prevention	Case analysis and technical review
Creation of information based on the guideline	Structured summary of results

3.1 RISK ASSESSMENT METHODOLOGY - FMEA

Starting from the principle that risk is the likelihood of something to happen multiplied by the impact (or consequences) of this action, where the possibility of identifying the problem can be integrated, the risk assessment matrix was divided in three main categories (columns) – likelihood, impact and identifying / solving the problem.

Following the ´hazard based risk assessment´ methodology - the FMEA/FMECA - used by a large number of industries, including the automotive and shipping industry, the risk assessment table .has for each of the three categories one single value and all have equal weight.

The advantage of this methodology is that it is overall used and known, has a generic technique, it gives an easy identification of the hazard consequences and it attempts to recreate reality (hazards lead to accidents, which have consequences) [MCGA 2007].

In the FMEA methodology each column has a value from 1 to 10, 1 meaning the lowest risk and 10 the highest risk, so when the three categories are multiplied, the total value can be from 1 (minimum) to 1000 (maximum).

It specifies that whenever the final multiplication result *exceeds 125* (e.g.: 5 x 5 x 5), there *should* be further investigation into the case, as it represents a considerable risk. Each time the number 7 or above appears in any of the categories, there is a need of revisiting this category, and something *must* be done.

Table 5 gives an overview of the weight assigned to each category. It sets the range between 1 (lowest risk) and 10 (highest risk) and suggests the action that should be taken.

Table 5 –Overall Categories Rating System: action to be taken according to the weighting number and hazard characteristics.

Hazard characteristic	Weighting number	Action
Lowest risk	1	Nothing needs to be done
Lower to acceptable risk	2-4	Something *could* be done
Moderate risk	5	Something *should* be done, further analysis
Considerable risk	6	Something *has* be done
Considerable risk	7	Something *has* to be done in a short period of time
High risk	8	Something *must* be done
Higher risk	9	Something *must* be done in a specified period of time
Highest risk	10	Something *must* be done in a short period of time

The differentiation between lowest and highest risk is based on the middle value number 5, which is considered a moderate risk. It is the borderline between the need of an action and the obligation of an action. The rating system in table 5 will serve as the base for the rating of all three categories of the design guideline matrix.

3.1.1 The three categories – Risk evaluation matrix division

The three evaluation categories give parameters to measure the risk associated with building elements, objects, products, or the combination of them, inside each room type. Each category represents a different aspect of the risk assessment theory and is shortly described below and further discussed in section 4.4.

The categories are named as follows:

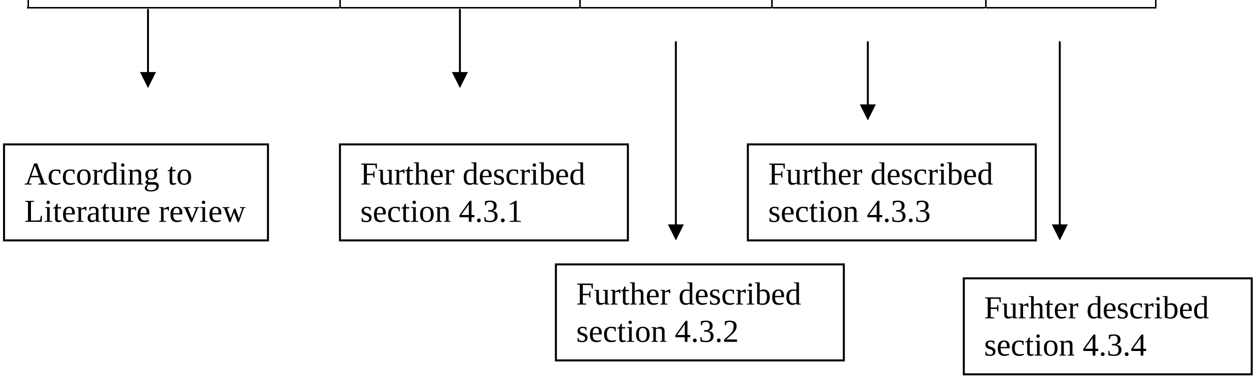
- **Category 1 – Likelihood by mechanism of Injury - X**

- **Category 2 – Impacts - Y**
- **Category 3 – Possibility of identification and solving the problem - Z**

All three values (X, Y, Z) are multiplied and result in a single final risk assessment number. Again following the FMEA methodology, the resulting number is analysed and gives the final risk level for each hazard studied (building element or object) and some description of how to act to avoid it or reduce its impacts. The table 6 illustrates the matrix division (the three categories).

Table 6 : The Division of the risk evaluation matrix

Hazard	Likelihood by mechanism of injury	Impacts	Identification and solving the problem	Final risk
Building element / object	**X**	**Y**	**Z**	**X.Y.Z**



3.1.1.1 The first category – Likelihood (X)

The likelihood shows the presence of hazards associated with the most common mechanism of injury and weights its probability of occurrence.

The identification of the hazard, and the association with its most common injury mechanism and its numerical rating system results from the analysis of the statistics on the most common injury mechanisms in relation to each precursor, the number of accidents related to each mechanism in a population, finally representing the likelihood of this mechanism of injury to happen.

3.1.1.2 The second category - Impacts on the child (Y)

This category weights the impact of the hazard (consequence of mechanism of injury) on the child's development:

- Long-term consequences on the development of the child. This category includes mortality rates. For now it excludes severe morbidity rates and other data, such as quality-of-life losses and loss of production, for lack of reliable data.

The intention is to match realistic statistic data and weight the injuries according to the possibility of death in a population and according to the number of related deaths within the total number of unintentional deaths.

3.1.1.3 The third category – Identifying the hazard and solving the problem (Z)

The third category rates the possibility of identifying the hazard and solving the problem. In this category it is important to note that the identification of the hazard is not enough to evaluate the risk when children are concerned.
Due to their development characteristics, children (especially between 0 and 4) are usually not able to recognize a potential hazard and to avoid it, so the possibility of fixing the hazard appears as an additional item, which is why an adult is responsible to identify the hazard and fix it. If children were to identify a hazard by themselves, this would not give a realistic value, considering that most of the time hazards for children are more of an attraction than a danger.

3.1.1.4 The final risk score (X.Y.Z)

The final risk score is the result of the multiplication of the numbers of the three categories described above. It reveals the most critical issues in the design of a room type, points out potential hazardous elements and objects, and suggests an appropriate action to prevent them. Some hazards may require immediate removal, some will be kept under observation, while still others can stay as they are (Table 5).

As the Health Impact Assessment (HIA) methodology describes, the objective is to find the best way to minimize the negative impacts and to maximize the positive ones.

The final risk score, as I said before, is the multiplication of the three categories (likelihood x impacts x possibility of identifying and fixing), and has a range between 1 and 1000. For each range of score an action is suggested (see section 4.5, table 19).

4 RESULTS

In the beginning of this chapter the most important items of the research are described, as they were often used in the proposition of the final solutions, creating a link between the research and the results.

The chapter concludes with a step-by-step description of the risk assessment design guideline, pointing out how each category is evaluated and how the risk levels for each one are weighted. A final case study illustrates the methodology and the desired results.

4.1 Most common accidents according to age

As I mentioned before, the relation types of accidents/victims have a direct connection to the development and age of the child. For example, if we look at babies in their first year, suffocation and choking are the most common accidents, followed by falls from beds and diapers´ changing beds.

Toddlers from 1 to 4 years are more likely to suffer injuries such as bruises and broken limbs. The number one cause of accidents in this age is burns or scalds, followed by falls.

The presence of a hazard is always associated with the potential injury mechanism, e.g. the cause of the accident. The recognition of the mechanism of injury can help to assign a weight to the present hazard. Table 7 shows the most common mechanisms of injury according to age.

Table 7: Most common mechanism of injury by age, United States

Age	Most common mechanism of injury	Secondary mechanism of injury
0 - 11 months	Suffocation and choking, falls	Burns and scalds, poisoning
1 - 4 years	Burns and scalds, poisoning	Falls and drowning
5 years	Falls	Drowning

Figures 10 and 11 illustrate the main mechanisms of injury in several countries. These charts indicate no association of the injury mechanism with the building element involved in the accident. They present fall as the most common mechanism of injury.

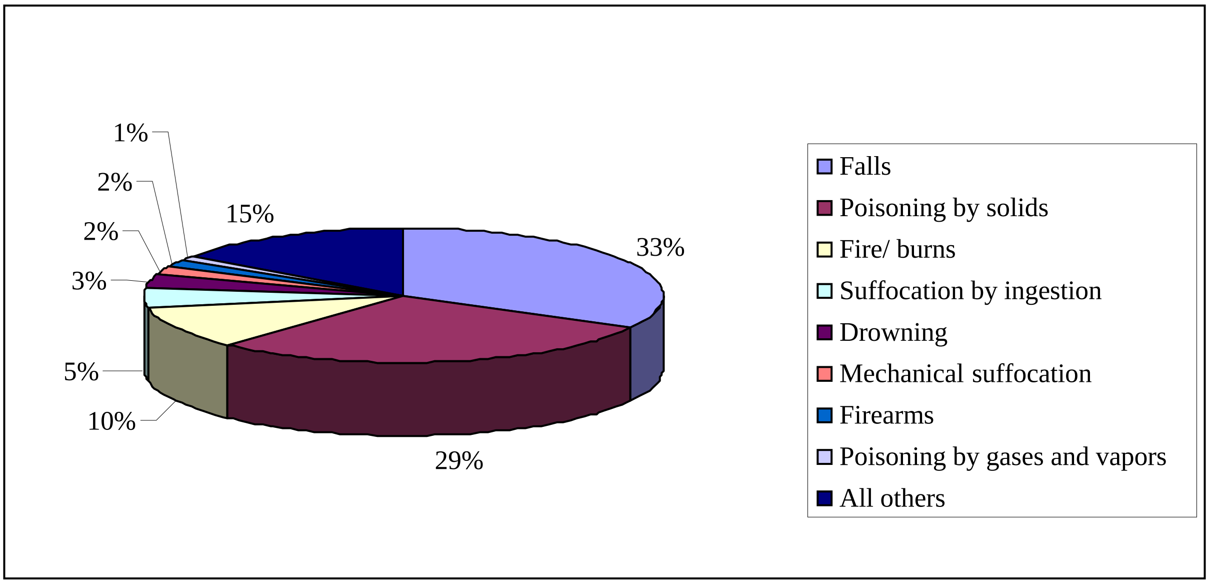


Figure 10 - Mechanisms of injuries in home accidents, USA [American N. Safety Council 2000]

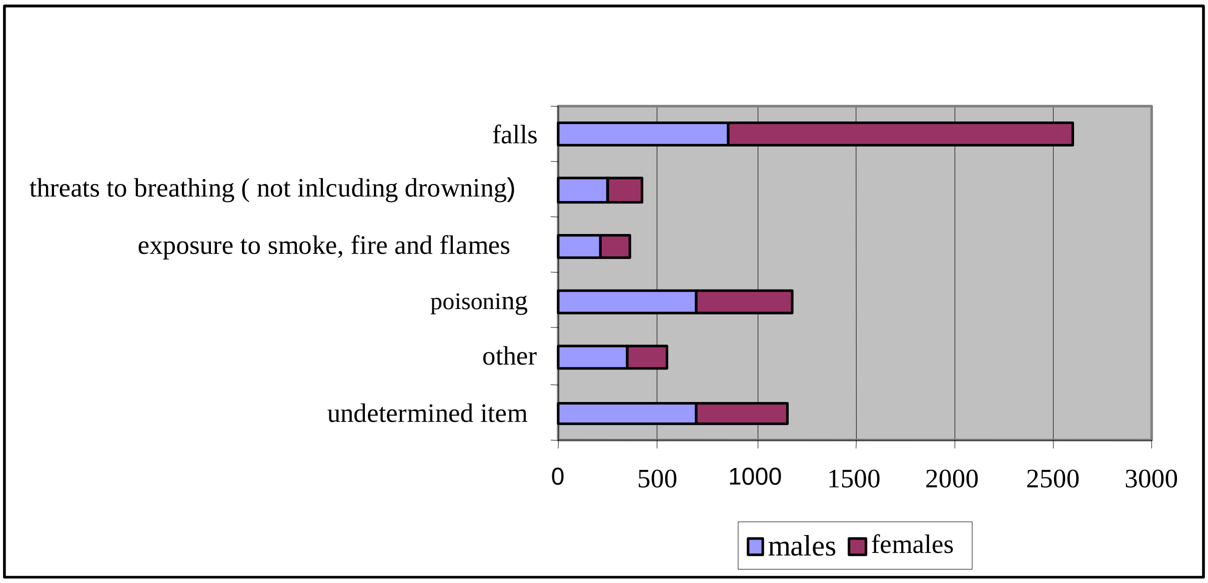


Figure 11: Home accidents mortalities by mechanism of injury, England and Wales, 2004 [Mortality 2004].

One can notice the difference in the statistics according to the region analyzed. In the USA, for example, the second leading cause of injury, in all ages, is poisoning, followed by burns and suffocation. In the UK, however, poisoning is in fourth place behind threats to breathing and burns.

4.2 Where accidents happen

As described above, there is some data about the leading causes of death according to age, but still few indications or information about where and how the accidents occurred, and more importantly, which housing characteristics or housing elements lead to the accidents.

Housing elements always refer to building factors (the constructional and design quality), so furniture, furnishings, equipment and appliances can influence the likelihood of a residential accident. The need to identify and classify these elements into risk levels can help decrease accidents.

The first step in determining the risk level for each housing element is to categorize the elements in a room type, according to the research review realized previously; to detect the most common accident or mechanism of injury in each room type, and to identify each hazard element linked to the accident. The conclusion of this part is to list every housing element and assign it a weight according to its mechanism of injury.
It is difficult to list in an ascending order the main rooms where accidents occur, since the statistics for each country vary according to the habits and culture of the population. For now, let us just look at the information from the HHSRS systems and the RoSPA.

The HHSRS data gives the following room types, listed in order of their accident potential for children - UK, 2000:

1. Living room
2. Kitchen
3. Bathroom
4. Staircases and corridors
5. Bedroom
6. Lifts
7. Laundry
8. Swimming pool
9. Garden

The ranking above shows that in the UK the likelihood of an accident to happen in the living room is greater than in a swimming pool. In the USA for instance, this difference is much smaller, where drowning appears as the most common accident in children ages 4 to 5 years.

Another more specific statistics realized by the Royal Society for Prevention of Accidents (table 8) shows the location of accidents within the home by age, providing interesting data about the number of accidents that happen to children inside each room type compared to elderly people (75+).

Table 8 – Location of the accident within the home by age group, UK

Location	0-4	75+
Lounge/study/ living/dining/play area	**5320**	**1349**
Unspec. home location (in/outdoor)	3409	3404
Unspec. indoors(home)	3025	2987
Bedroom	**2835**	**1616**
Kitchen/ utility room	2090	1215
Garden/grass/ plant beds	1843	1165
Stairs inside	1612	697
Hall/lobby/passage/corridor	710	366
Yard/driveway/path/hard surface beside house	678	670
Bathroom/ toilet	675	797
Porch/threshold	332	316
Patio/terrace/veranda	159	83
Stairs/steps –outdoors	158	179
Other	127	1673
Landing	105	69
Conservatory	65	37
Other indoors (home)	55	45
Garage	38	98
Tool/potting/coal/outbuilding	21	37
Balcony	17	5
Cellar/basement	9	3
Store/cloak room/cupboard/pantry	5	6
Loft/attic	3	7
Greenhouse	1	15
%	17.7	12.8

After recognizing the main room types where accidents happen, another point has to be analyzed: the hazards in each of these room types. Some statistics, especially from the UK, show a list of accident locations inside the home, including some of the building parts. Table 9 illustrates a statistics produced by the HASS, in which the number of accidents according to building elements is evaluated and compared to the total number of accidents.

Table 9: Percentage of injuries from the total of accidents, by location of the accident within the home, children between 0 and 4 years, UK

Location	0-4 years	Total of accidents	% from total of accidents
Lounges/ study/ living/dining / play area	5320	15201	**35**
Balcony	17	62	**27.4**
Bedroom	2845	11297	**25.2**
Hall/ lobby/ passage/ corridor	710	2921	**24.3**
Store/ cloak room/ airing/cupboard/pantry	5	22	**22.7**
Conservatory	65	297	**21.9**
unspec. indoors (home)	3025	14611	**20.7**
Other indoors (home)	55	274	**20**
Kitchen/ utility room	2090	12778	**16.36**
Patio / terrace/ veranda	159	919	**17.3**
Bathroom / toilet	675	4627	**14.6**
Stair inside	1612	11043	**14.6**
Porch/ threshold	332	2333	**14.2**
Landing	105	784	**13.4**
Cellar/ basement	9	68	**13.23**
Unspec. home location (in/outdoors)	3409	26928	**12.65**
Garden/ grass/ lawn/ plant beds	1843	14592	**12.6**
Stair/ steps –outdoors	158	1404	**11.25**
Yard/ driveways/ path/hard surfaces beside house	678	6215	**10.9**
Other	127	3286	**3.8**
Garage	38	1320	**2.9**
Greenhouse	1	61	**1.6**
Loft/ attic	3	313	**0.95**
Outbuilding	21	416	**0.48**

HASS 2002

The collected data made it possible to list the room types, evaluate their accident potential and the most common mechanism of injury in these room types, so that the first part of the risk evaluation table can be completed, as shown in section 4.4.1.

4.3 THE CREATION OF THE RISK EVALUATION MATRIX

As described before, the risk evaluation table is divided in three categories according to the FMEA methodology: likelihood by mechanism of injury (X), impacts (X) and possibility of identifying and solving the problem (Z).

This section show how these categories are organized and how they get to results which will be inserted in the final risk evaluation matrix.

4.3.1 CATEGORY 1: LIKELIHOOD BY MECHANISM OF INJURY (X)

After the identification of the room types in which accidents happen, the building elements, objects and products involved in the accidents have to be listed, which means listing the hazards present in each room. After identifying a hazard, the most common mechanism of injury (the cause of an accident) can be associated with each hazard. This list with potential hazards was created using statistics and literature reviews (HHSRS data).

The association of the mechanism of injury was made by identifying the most common accidents related to each hazard, using concrete statistical data to that end. This mechanism of injury received a risk value according to its likelihood to happen (see Methodology), so that it can be inserted in the first column in the risk assessment matrix.
For example, the most common mechanism of injury for a slippery floor are falls, because this is the most common type of accident that occurs when considering a slippery floor as hazard.

To put it simply, **Category 1 (X)** can be completed through the following steps:

1) Identification of hazards and precursors
2) Association of a mechanism of injury with each hazard (research review)
3) Collection of data on each mechanism of injury: X1 = number of related accidents/ population ; and X2 = number of related accidents/ number total of accidents
4) For both X1 and X2 a weighting system was applied to assign them numbers between 1 and 10.
5) Assuming that a final single number between 1 and 10 has to be achieved according to the methodology in chapter 3, the result X is the simple average value of X1 and X2.

4.3.1.1 Identifying hazards and precursors, associating the mechanism of injury

According to the National Academy of Engineering, an accident precursor is:
"Any event or group of events that must occur for an accident to happen in a given scenario. A precursor is an event or situation that, if a small set of behaviours or conditions had been slightly different, would have led to a consequential adverse event" [Corcoran 2002].

This concept is very important in the study of injury causes. Precursors include not only *objects and elements*, but also humans´ *behaviors and development*. Trying to foresee these precursors in each situation is very important for accident prevention especially with regard to children, who are still in a development process and often show unpredictable behavior.

All usual and unusual dangerous situations have to be considered as potential precursors, i.e. every time a situation is identified (or an object is recognized) as being potentially hazardous, something has to be done. If one fails to recognize it or ignores the potential degree of danger, the risk of an accident gets higher.

Weighting of precursors is not always simple, especially when no behavior study or no development tests have been made. Children’s interaction with the environment and their capability of recognizing hazards varies with age and requires a detailed study. Therefore, the identification of *behavior and development precursors* was kept outside this risk evaluation for now and only precursors which involve objects and elements were analyzed.

The identification of the accidents´ objects and elements precursors can also be very difficult, because some accidents are not frequent and can involve elements never related before. This identification includes the probability of occurrence, level of consequences (impacts), and its context. It involves gathering information about accidents (location, mechanism of injury, objects and elements involved), interpreting and analyzing this information (e.g. the kind of building elements involved and the connection between building element and mechanism of injury), compiling data, comparing statistic data and drawing a final conclusion on the identification of the precursor.

In this particular case, the intention is to identify accident precursors by recognizing potentially dangerous elements, objects and building parts that could create an accident scenario for a 0 to 4-year-old child. The next step is to attribute a weighting, i.e. a number to a hazard, which is subsequently inserted in the risk evaluation table, as already described.

The identification and numerical classification of each hazard is made by analysis of the statistical number of accidents related to each precursor (building element, object) and by mechanism of injury: falls, burns, poisonings…

Table 10 shows the number of registered accidents related to the building part involved and the correspondent most common mechanism of injury (the category “most common mechanism of injury” was added to the original table using literature review).

In the table 9, each building element was associated with the most common mechanism of injury, according to data collect in the HHSRS database. One can notice that whenever a floor type appears, the most common mechanism of injury associated with it is fall. Suffocation occurs mostly when small products and objects are involved, as for example on sofas and couches where pillows usually lie.

Table 10 - Number of accidents related to building elements and the most common mechanisms of injury according to the building element, UK, 2002

Building element	Number of accidents	Most common mechanism of injury
Floor unspecified	301 432	Fall / cuts
Floor wood	83 353	Fall / cuts
Bed not bunk	56 273	Fall / suffocation
Sofa/ couch	43 850	Fall / suffocation
Floor concrete/ stone	27 675	Fall
Door unspecified	27 306	Struck against
Floor – ceramic/ tiles	18 922	Fall
Armchair	16 380	Fall/ struck
Shelf / ledge	13 694	Struck
Table / dining/ table cloth	13 530	Burns/ suffocation
Cupboard	12 628	Struck / falls
Bedside table	11 398	Cuts/ struck
Floor wet or polished	9 758	Falls
Drawers	5 064	Cuts / piercing/ falls
Curtains	4 223	Suffocation
Cupboard no glass	4 018	Strucks
Furniture	3 547	Falls/ strucks/ cuts
Stand/ rack	3 342	Falls

HASS - RoSPA 2002

In table 11 some hazards and the most common mechanisms of injury are identified for the room type kitchen, as an illustrative example of how the first part of the risk assessment guideline is done.

Table 11 – Potential hazards inside the kitchen and their most common mechanisms of injury

Potential hazards according to statistics	**Most common mechanism of injury**
Dishes placed on the lower cupboards	Cut
Oven upper level	Burn
Slippery floor + glass cupboard	Cut/ struck
Cooking plate buttons on the side	Burn

4.3.1.2 Mechanism of injury association

One can notice that in some cases, there are two or more mechanisms of injury for one hazard, because sometimes all of them appear with the same frequency or because if the hazard's content changes (for instance the location of the oven changes) another mechanism of injury can appear (in this case not only burns, but also falls from the oven).

The association of several mechanisms of injury will appear quite often once the hazard situation changes. In those cases, for the risk assessment evaluation, the hazard will appear as many times in the table as it has different mechanisms of injury. The final risk number of a hazard is considered the one with highest final score (more examples in the case study 4.5.1), but the more frequently it appears on the risk assessment matrix, the bigger is the risk it poses.

4.3.1.3 The weighting system

After identifying the most common mechanisms of injury for each hazard, table 11 shows the mechanisms of injury in the studied age group and their frequency and number of occurrences in a population.

The table 12 represents the percentage of the population affected by the mechanism of injury and its percentage in the total of unintentional injuries, considering a population of 20,060,672 individuals and the total of unintentional injuries in this case 2,282,902 cases.

Table 12 – Percentage of a certain mechanism of injury in a 100 population and its percentage in the total of unintentional nonfatal injuries, 2004, United States; all races; both sexes; ages 0-4

Mechanism of injury	**Numbers of injury**	**% of 100 population X1**	**% in the total of unintentional injuries X2**
Fall	1 014 617	**5.50**	**44.40**
Struck by/ against	398 865	**1.98**	**17.47**
Foreign body/ suffocation	122 850	**0.61**	**5.38**
Cut/pierce	92 939	**0.46**	**4.07**
Overextension	82 676	**0.41**	**3.62**
Fire/ burns	69 100	**0.34**	**3.02**
Poisoning	53 216	**0.26**	**2.33**
Drowning	2 561	**0.01**	**0.11**

WISQARS, ICD-10 2006.

For example, considering that in case of an accident the risk of it being a fall-related accident is 44% (percentage of the all unintentional injuries, i.e. in every 100 accidents, 44 have fall as injury mechanism), this would rate the injury mechanism “falls” with a higher weight than compared to drowning, which appears with 0.11% in the statistics (i.e. for 1000 accidents, one is caused by drowning).

The likelihood of an injury mechanism to happen is considered the *average value* of the number of related accidents in a population (X1) and the percentage of this kind of accident in the total number of unintentional accidents (X2). The two subcategories X1 and X2 receive a weighting which follows the principles of the FMEA methodology (1 to 10).

Table 13a illustrates the rating system for the number of related mechanisms of injury in a population - X1, using as base data from table 11.

Table 13.a – Number of accidents of a certain type in a population of 100 children (X1)

% of accidents in 100 population (X1)	Weighting points
> 10.0	10
9.9 – 7.5	8 – 9
7.4 – 5.0	6 – 7
4.9 – 2.5	5
2.4 – 0.1	3 – 4
0.09 – 0.0	1 – 2

The rating principle is as follows: The mechanisms with a percentage of >10% accidents in a population are considered the highest risks and therefore receive a weight of 10. Accidents with a rate of <5% are assigned 5 points, while accidents below 0.1% are given weighting point (see methodology).

As for the second subcategory of the category 1, the number of related accidents in the total of accidents (X2), another method to associate a weight with the percentage of related accidents in the total of accidents was used, namely the same used for thermal comfort studies.

In the thermal comfort evaluation, not more than 20% of the people in a room should feel uncomfortable; when it happens something *should* be changed in the place. As the percentage of non-satisfaction gets higher, the way of interaction with the space changes, ranging from possible changes to drastic actions.

Extracting the methodology from the system, we find that every time the percentage hits 20% or above, something *should* be done about it. This argument fits this category in the same weight category as the risk level 5. So a rating system could be created to evaluate the percentage of related accidents in the total of unintentional accidents as shown in table 13.b.

Table 13.b – Percentage of accidents of a certain type in the population, from the total of accidents (X2)

% of total of unintentional injuries (X2)	**Weighting points**
100 - 50%	10
49 – 40%	8 – 9
39 – 30%	6 – 7
29 – 20%	5
19 – 5%	3 – 4
0 – 4%	1 – 2

When the mechanism of injury represents between 10% and 20% of the cases, something *has* to be reviewed, so the weight given is 5; when the percentage exceeds 50%, something *must* be done in a short time, so it is given the weight 10 (see reference table 5).

It is easy to understand considering for example that the chance of an accident to happen to a child between 0 and 4 years is over 20%, meaning in each 10 cases 2 accidents will happen. It is clear that there must be a more precise study on the hazard, so the weighting number must be at least 5, according to the methodology used (chapter 3).

To achieve the final score of the first column of the risk assessment matrix, the two results from the table 13.a and 13.b have to be taken into consideration. The final score is the *average* of the two previous values (X1 and X2) as shown in table 14.

Table 14 - Weighting systems likelihood: weight according to mechanism of Injury

Mechanism of injury	**Weighting System (X)**
Fall	**7**
Struck by/ against sth.	**4**
Foreign body/ suffocation	**3,5**
Cut/pierce	**3**
Overextension	**2**
Burns/ Scalds	**2,5**
Poisoning	**2**
Drowning	**1**

The final weight is the one to be inserted in the risk assessment table. In this part, as the likelihood of an injury to happen is evaluated, one can see that falls are the most common mechanisms of injury overall, they are one of the most frequent that occur in a population and are the most common accidents.

As I mentioned before, falls are not only a problematic issue with this age group (0 to 4 years), they also present a frequent accident type for elderly people and need better study.

On the other hand, striking against or being struck by objects is a common accident in small children, and is much more common than in the elderly (which does not mean that few accidents happen to elderly people). As far as its frequency is concerned, it appears in the border limit between the need of an action and the obligation of an action (4, 5).
In this category, burns, poisoning and drowning are listed with the weighting point 1, because given the overall number of accidents and the number of accidents in the population, they are not so frequent. Drowning, for example, has a really low frequency of 1 case in 10 000 children.

4.3.2 CATEGORY 2 - IMPACTS ON THE CHILD (Y)

The impact on the child can be measured with two main data: the impact as short-term consequences (hospitalization rates, emergency room statistics) and the long-term consequences, considered here as the mortality rate of the mechanism of injury (Pfeiffer 2006).

At this stage of research, the short-term consequences are left beside, because there was not enough reliable information available. The long-term impact data will give an idea of how fatal the accident can be.

Long-term consequences: include death rates (in this research, data such as quality-of-life losses, life years lost, effects on motor and cognitive skills development are not taken into account).

The need of weighting each injury according to its impact on the child appeared as an important issue in the risk level evaluation. It gives real statistic numbers that show the dimension of the impact on the child, which can be considerably different from the impact on an adult (for adults, there is no distinction between long and short-term consequences).

4.3.2.1 The weighting system

As I mentioned before, the impact of the most common types of injuries was classified using some statistic data to create a realistic scenario. Data from the American National Centre for Injury Prevention and Control were matched together with data from the EHLASS, and final data conclusions could be made, as shown in the tables below.

Table 15 give us an overall view of the main mechanisms of injury and the related number of deaths in a population, and the percentage of related deaths in the total of unintentional injuries deaths.

Table 15 –Percentage of deaths by a certain type of injury in the total of unintentional deaths, 2004, United States; all races; both sexes; ages 0-4

Mechanism of injury	Number of deaths	Total of unintentional deaths	% in the total of unintentional deaths (Y)
Suffocation	850	2 693	**31.50**
Drowning	492	2 693	**18.26**
Fire/ burns	490	2 693	**18.25**
Fall	70	2 693	**2.60**
Poisoning	31	2 693	**1.15**
Struck by/ against	19	2 693	**0.70**
Cut/pierce	7	2 693	**0.25**
Overextension	0	2 693	**0%**

WISQARS 2006

The table above can give us interesting values when comparing numbers of deaths to numbers of related accidents. For instance, in terms of falls, the number of occurrence of deaths by fall is 4 in a population of 100 000 (between 0 and 4).

The column “percentage of unintentional deaths” gives important values for the weighting system and is inserted in the **Category 2, Y**.

Considering death the worst consequence of an accident (there is no further development), the probability of death can show how risky the accident is to the development of the child, and assigns a number, which represents the risk of death, to the mechanism of injury. The greater the number (1 to 10), the greater the probability of death.

The mortality data is assessed using data from death certificates. Most of the data was collected from the American National Centre for Injury Prevention and Control and from the CDC´s National Centre for Health Statistics. Crossing the data produced some new tables with a more specific overview.

Analyzing table 15, some conclusions which helped with the weighting system of the long-term impact could be drawn:

- Drowning: the possibility of death is the highest – for each 100 non-fatal drowning accidents, there are 19 deaths to children between 0 and 4. At the same time in a population of 100 000 children between 0 and 4 of age, 2 die from drowning, and from a total of 100 fatal accidents 18.2 are due to drowning, i.e. drowning is responsible for 18.2% of unintentional deaths.

- Fire/ burns: the possibility of death by burn is 2 in 100 000 of a population of 0 to 4 years. Fire-related accidents are responsible for 18.2 of fatal deaths in a population of 100 (0 to 4 years), meaning it is responsible for 18.2% of unintentional deaths.

- Suffocation: the possibility of death by suffocation is 2 in 100 000 in a population of 0 to 4-year-olds. When a fatal accident happens, the possibility of suffocation being the death mechanism is 32.5 in a population of 100 (0 to 4 years), which makes it responsible for 32.5% of unintentional deaths.

- Poisoning: the possibility of death by poisoning is 1.5 in 1000 000 population (0 to 4 years). The poisoning-related accidents represent 1.15% of all unintentional deaths.

- Cut/ pierce: the possibility of death by cuts or piercing is 9 in a 1000 000 population between 0 and 4 of age. Cuts and pierce-related accidents are responsible for 0.7% of all unintentional deaths.

- Falls: the possibility of death by fall is 3 in a 100 000 population between 0 and 4. Fall-related accidents are responsible for 2.6% of unintentional deaths.

- Struck against/ by: the possibility of death by striking against/ being struck by objects is 4 in a 100 000 population (between 0 and 4). Struck-related accidents are responsible for 0.7% of unintentional deaths.

Table 16 illustrates the percentage of fatalities in all deaths and corresponding weighting system and the corresponding weighting system to be adopted for the Classification 2 of the final risk assessment matrix.

Considering that the highest percentage of the unintentional deaths was over 31%, i.e. the most risky one, the weight 10 (from 1 to 10, according to methodology) was assigned to every value above 30%. Considering 15% as the middle value, the weight 5 was given. The lowest percentage that appeared was 0%, so for this one the weight 1 was assigned.

Table 16 – Percentage of fatalities in all deaths and corresponding weighting system (Y)

% of fatalities in all unintentional deaths	**Weighting points**
30.1 - 100.0	10
22.6 – 30.0	8 – 9
15.1 – 22.5	6 – 7
7.6 - 15.0	5
1.1 – 7.5	3 – 4
0.0 – 1.0	1 – 2

Table 17 – Mechanism of injury and the corresponding percentage of the total of accident-related fatalities, 2004, United States, both sex; ages 0-4

Mechanism of injury	**Portion in all accident-related fatalities**
Suffocation	**31.50**
Drowning	**18.26**
Fire/ burns	**18.25**
Fall	**2.60**
Poisoning	**1.15**
Struck by/ against	**0.70**
Cut/pierce	**0.25**
Overextension	**0**

WISQARS 2006

By matching table 16 and table 17 where each correspondent mechanism of impact is associated with its percentage of total of unintentional deaths, the final weighting table 18 to be used for the final risk assessment evaluation could be produced.

Table 18 - Weighting system according to the impacts on the child (Y)

Mechanism of injury	Weighting points
Suffocation	**10**
Drowning	**7**
Fire/burns	**7**
Fall	**4**
Poisoning	**3**
Struck by/against	**2**
Cut / Piercing	**1**
Overextension	**1**

It is interesting to see that in the classification of impacts, suffocation appears as the most risky of them and falls follow in 4th place in the UK. This is easy to understand when one evaluates the fact that for each 100 fatal unintentional accidents, over 30 are due to suffocation (in children between 0 and 4). By contrast, only 2.6 have fall as mechanism of death for every 100 accidents.

4.3.3 CATEGORY 3 - POSSIBILITY OF IDENTIFYING THE HAZARD AND SOLVING THE PROBLEM (Z)

The possibility of identifying and fixing the hazard is considered another category, because it gives weight to the possibility of a reaction to the problem. In some cases, fixing the problem is easy, as for example a gas pipe, but identifying this problem is much more complicated, as gas in this case is odorless. Similar cases happen very often, especially when construction elements are involved.

It is interesting to note that with regard to children, the possibility of identifying the hazard not necessarily decreases the risk of an accident. In some cases it can be the opposite: Children tend to turn their attention to potential hazards, don't recognize them and, owing to their natural curiosity, tend to get into contact with the hazard.

As the pure identification of the hazard appears not as an efficient means of judging the possibility of reacting to the problem, another category called the possibility of fixing the hazard or solving the problem was added to the risk evaluation matrix.

This possibility of fixing the problem requires an adult who should be responsible enough to identify the risk and without legal pressure, fix it.

4.3.3.1 The weighting system

Knowing the hazard identification and possibility of solving the problem is very subjective and depends on personal judgments, some limits were imposed to have a better overview of this evaluation.

A hazard easy to identify may be everything that an adult in normal health can notice without having to search for the problem. Elements that fall in this category include: identification of slippery floors, glass cupboards, glass doors, dangerous positions of furniture, electric equipment, medicines...

The opposite classification, hazards hard to identify, can be everything that is potentially hazardous but not visible nor obvious to a normal adult. Gas leaks, heater temperatures, hot water from the pipe, electrical problems and short-circuits fall in this category.

Objects and building elements easy to be fixed are all elements that can be repaired in less than one day after identification (taking as base the 1 day standard used in the UK for classifying problems inside dwellings). Elements considered hard to be fixed require more than one day of work.

So far, this thesis only considers the time barrier in the evaluation of the possibility of fixing and solving the problem. The economic degree of difficulty, the professionals is taken into account for the classification, considering only the costs to solve the problem. The cost of remediation is considered to be hight, medium or low, by now, using personal judgement for this classification. The possibility of fixing the problem is also classified using the same parameters (high, medium and low possibility of identification).

From this classification a matrix of the weighting system could be elaborated, as shown in table 19.

Table 19 – Weighting system according to the possibility of identifying the hazard and costs to solve the problem (Z)

Hazard	Possibility of identifying the problem	Costs of remediation	Weighting points (Z)
Hazard	High	Low	1
		Medium	2-3
		High	4
Hazard	Medium	Low	5
		Medium	6
		High	7
Hazard	Low	Low	8
		Medium	9
		High	10

The harder the identification and the costs to fix the hazard, the higher the assigned number of points (from 1 to 10 according to the methodology). One notices that a low possibility of hazard´s identification implies in a high score, even if the cost of remediation are low.

4.3.4 THE FINAL RISK ASSESSMENT MATRIX

As explained in the methodology, the final risk assessment matrix is divided in three categories whose multiplication produces the final risk level of each hazard inside each room type. The three categories, as described in chapter 4.4 produce weighting points to be inserted in the final risk assessment table.

The final risk is represented as a score between 1 and 1000, according to the FMEA methodology. Each resulting score represents a recommended action to be taken as shown below in table 20. The methodology used to define the weighting number is the same as the one used in FMEA risk analysis processes and the one adopted by the WHO Hazard's certification project.

Table 20: Final risk level weighting system – Recommended action according to final risk score (X.Y.Z)

Final risk weighting score	Characteristic	Recommended action
1-63	Lower risk	No immediate action
64-124	Existing risk	Something *could* be done
125-216	Moderate risk	Something *should* be done, need of observation
217-342	Higher risk	Something *must* be done, no time pressure
343-511	Higher risk	Something *must* be done in a specified time
512-728	Higher risk	Something *must* be done within a short time
729-1000	Higher risk	Something *must* be done immediately

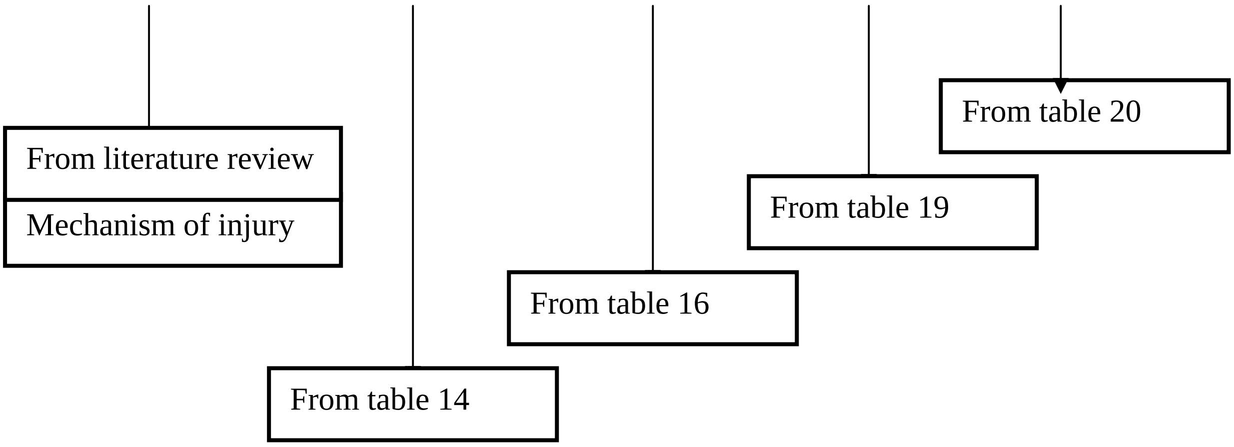
.

The table illustrates that every time the score reaches 125 (5x5x5) or higher there is the need for an action, i.e. the building element (object) represents a potential hazard to the child and something has to be done. Beyond the score 343 (7x7x7) something *must* be done in a short period of time as it poses an even higher risk to the child. Above the score 729, there is a very high risk of an accident and immediate action must be taken.

Table 21 shows the main structure of the final Risk Assessment Matrix

Table 21 – Risk Evaluation Matrix

Object or building element – Hazard	Likelihood by mechanism of injury	Impacts	Identification and fixing the problem	Final risk
Building element / object	**X**	**Y**	**Z**	**X.Y.Z**



The application of the risk assessment matrix will be shown in the following case studies. It is important to remember that the risk assessment table will give the parameters for the identification of safety design failures and will offer new suggestions.

4.4 CASE STUDIES

4.4.1 Kitchen

According to the Royal Society for Prevention of Accidents in the UK, the kitchen is classified as the second most dangerous place in the house for a child between 0 and 4 years old, being exceeded only by the living room (see table 1).

As statistics show, most of the accidents in the kitchen happen while an adult is doing some household activity in the kitchen or when the child is alone in the kitchen.

- The most common accidents in the kitchen:

Burns are the most common accidents, followed by falls, cuts and poisoning.
Burns and scalds are usually the consequence of tipping over pans containing hot liquids, hot water from the sink, hot cooking plates and ovens which typically affect hands and arms.

Falls usually happen because of slippery floors, climbing on furniture and objects such as drawers and cupboards. Cuts are in most cases the consequence of a child playing with a sharp object without an adult's attendance or they are caused by a fall.

Poisonings are usually due to the ingestion of cleaning products, medicines, and other hazardous products. This kind of accident mostly happens to unattended children or while an adult is occupied with household activities. The kitchen and laundry are typical places for poisonings, because most people store cleaning products in those room types.

- Most affected group:

Children from 1 to 4 years. Their level of curiosity and development characteristics add to the risk. Mothers who spend most of the time at home tend to carry out a majority of their activities in the kitchen and, consequently, children also spend more time in this room type.

1) Identification of precursors and hazards

Statistic information from the HASS provides a general category of articles, products and features involved in accidents. From this list, some building elements and objects could be selected according to each room type (see Appendix). As a consequence, the hazards inside the kitchen could be identified and the most common mechanism of injury was associated with each hazard.

The identification of hazards and mechanisms of injury leads to another classification on the risk assessment table.

2) Risk assessment design guideline

As I mentioned before, the most common mechanism of injury leads to the likelihood of this accident to happen (X) and the impact of this injury to the child (Y). The possibility of identification of the hazard and the possibility of fixing it (Z) have to be analyzed.. The final risk level is the multiplication of the three variables and results in the recommended action for each situation (methodology).

The risk assessment matrix for the kitchen is illustrated in table 22. Hazards such as ovens, dishes, furniture and electric appliances are supplemented by information on location, position, height, material, and combinations with other sources of danger.

Each hazard receives a final risk score which in turn points to the action to be taken against this hazard.

Table 22 - Risk assessment design guideline

Potential hazards according to statistics	Most common mechanism of injury	Likelihood (X)	Impact (Y)	Identification and possibility of fixing it (Z) **	Total Risk level X.Y.Z
Slippery floor*	Fall	7	4	7	196
Slippery floor*	Cut	3	1	7	21
Drawer beside cooking plate*	Fall	7	4	5	140
Drawer beside cooking plate*	Burn	2	7	5	70
Oven upper level*	Falls	7	4	3	84
Oven upper level*	Burn	2,5	7	3	52,5
Oven lower level	Burn	2,5	7	3	52,5
Slippery floor + glass cupboard*	Fall	7	4	7	196
Slippery floor + glass cupboard*	Cut	3	1	7	21
Slippery floor + glass cupboard*	Struck	4	2	7	56
Dishes placed on the upper cupboards*	Fall	7	4	2	56
Dishes placed on the upper cupboards*	Cut	3	1	2	6
Cooking plate buttons on the front	Burn	2,5	7	2	35
Knife or cutting objects + unlocked drawers	Cut	3	1	1	3

** Cases with two mechanisms of injury*

***Assumptions*

Table interpretation:

According to the final risk level of each hazard the following conclusions can be drawn:

- While a slippery floor is a single hazard building element, it comprises two main mechanisms of injury: falls and cuts, falls being the most common of the two. The final risk level indicates that for slippery floors with the injury mechanism fall, the final risk is 182 – which, according to table 22, represents a moderate risk and recommends that something should be done. When the second mechanism of injury is analyzed, the slippery floor represents a much lower risk, with a final risk level of 21. The final risk level considered for slippery floor is always the one with highest final risk score.

- When analyzing the location of drawers besides cooking plates, two other mechanisms of injury arise, resulting in two different final risk scores. If the mechanism of injury is fall, the risk level is 130, i.e. it represents a moderate risk and something should be done about it (there is the need of observing the problem). When the mechanism of injury is burn, the risk level decreases to 70, which represents an existing risk and means that something could be done about it. The final risk level for the hazard "drawers besides cooking plates" therefore is 180 – something should be done about it.

- The location of the oven also comprises two mechanisms of injury: falls and burns. Burns are the most common of them, but falls are also frequent once children climb on the oven door. The risk level for the injury mechanism fall is 78 and for burn 42. It suggests action to be taken once the risk is present.

- The association of slippery floors with other furniture like glass cupboards, for example, involves three mechanisms of injury: falls, cuts and struck against. When the mechanism of injury "fall" is involved, which is the most hazardous of the three, it results in the risk level 182 and represents a moderate risk, which means something should be done.

4.4.1.1 Potential solutions:

After analyzing the table above, some conclusions can be made about changes in design attitudes when planning the kitchen. Table 24 shows how the risk level can increase once the location of an equipment or furniture changes. What mostly happens in these cases is that another mechanism of injury is added to the hazard, as for example when one changes the oven's position from the lower level to the upper level. In both cases the most common mechanism of injury are burns. But once the position of the oven gets higher, the it gets more attractive: Children may not just open it and get burned, they also may try to use the oven door as a climbing element.

Another point is that needs careful study is the location of glass cupboards and glass doors in the presence of a slippery floor. The combination of these two elements adds two mechanisms of injury to the most common hazard (fall) associated with slippery floors, namely cuts and struck against.

Some rules were developed according to the table analysis and literature review pointing out what architects and contractors could do to avoid the most common accidents in the kitchen:

- Do not place elements which children can climb on near cooking plates and ovens. Drawers shouldn't be placed close to cooking plates, because children can use them as steps to climb.

- Elements to sit on (chairs, high benches…) shouldn't be placed close to sinks and cooking plates either

- All stoves should be child-proof to avoid electrical shocks

- Smoke detectors and alarms should always be installed in the kitchen

- Matches and lighters should be placed in a child-proof locked drawer.

- Cutting tools and potentially hazardous products should be placed in a safe place with child-proof locks. They should be placed in the higher drawers, making it harder for small children to access them.

- A good lighting in the kitchen can avoid cuts accidents.

- All cleaning products must have child-proof caps.

4.4.1.2 Suggested technology

Special attention should be paid to the kitchen as it is considered one of the most accident-prone places in the house. Due to this fact, the entrance to the kitchen should be monitored all the time, never forgetting that accidents usually happen when they are least expected. A 24 hour, 7 days per week safe access control of the kitchen could avoid most of the accidents, especially in small children, who cannot judge the potential risks in the kitchen.

The idea is to create a system to identify who may go inside the kitchen, if this person is alone, and to make it react according to the potential risk of an accident.

Assuming that a small child enters the kitchen alone, this would be detected by the system and all potential risk elements would be locked, for instance the cooking plate cannot be turned on, the oven cannot be opened or the drawers which have potentially hazardous objects inside would be locked.

The identifying system could work with weight sensors (load cells) to find out who is getting inside the kitchen (if it is a child, he has less weight than an adult), and if he is alone or not. This technology could help avoid some accidents which happen when children are unattended. These weight sensors already exist and are often used in safety devices by the industry.

Another technology to prevent accidents inside the kitchen when children are not alone is an alarm system which would recognize potentially dangerous situations and subsequently go off so that an adult can check what the child is doing. For example, when the mother is cooking and the child is playing in the kitchen, usually the mother cannot pay all of her attention to the child, so the sensor would detect if the child was getting too close to the cooking plate and oven, or if the child was trying to open a drawer which has potentially hazardous tools inside. Whenever pre-programmed patterns of dangerous actions are identified, the alarm would ring. This technology could use proximity sensors and movement sensors.

Another technological suggestion is the creation of knobs and turn on-off buttons that only work with certain digital fingerprints, or that do not work with certain fingerprints. With this technology, certain drawers and objects do not work, or do not open, when children try to use or open them. This technology could be applied not only in the kitchen, but also on specific doors, closets, bathrooms, certain electric devices, etc…

The accident smart oven is an existing technology with the idea of creating a cooking plate that can prevent the cooker from potential accidents and which could react to potentially dangerous situations. For example, the stove has a screen which shows some warnings such as, “it is advised to use the cooking plate behind, specially if there are children around.” , “always keep pans handles to the inside of the stove, this avoids children pulling them”.

This stove would have a security on-off button, preventing children from turning it on or off. It must be fixed to the wall or floor to prevent children from knocking over the whole stove, it would have a security device which would come up and down in front of the cooking plates when they are hot and a child is around.

4.4.2 Other Building Elements

a) Furniture

Furniture with glass or glass doors and windows should always be protected by a glass film, which is not visible and can avoid deep cuts

Attach furniture to the wall or the floor if they are not heavy enough not to tip over if children climb them.

Never place furniture which children can climb near windows, especially when the room is located above ground level

Avoid sharp corners, and cutting materials, such as sharp metal corners

b) Windows and Doors

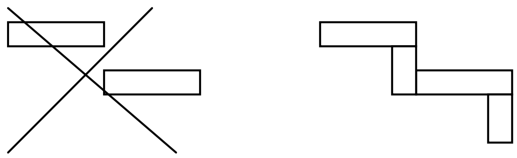
Glass doors and windows with dimensions of over 1.5 x 1.5m should have stickers or signs on them that can be easily seen from a distance. In some countries there have been studies that suggest to include this measure into the building code. Many accidents, not only in children, happen because glass doors and windows are not seen.

Windows should always be made of laminated glass (temperate) or similar material. In multi-story buildings windows should always have a child-proof security lock. The guardrail should be designed according to the International Building code R315, with a height not exceeding 106.7cm and not going below 91.40cm and should have a rail spacing between 3.75cm and 7.00cm.

c) Stairs

The most common accidents associated with stairs are falls. Consequences of those falls are cuts and fractures. Avoid stairs with more than 15 steps without a landing platform. The landing platform should be correctly dimensioned, never being smaller than 60cm in width; ideally, it is designed with the same width dimension as the length of the step.

Steps should always have a base between 26cm and 30cm, and a height between 15cm and 18cm.
Steps should be full steps, which helps to avoid falls. Open steps can act as hazards, because children and adults can slip through the open step and fall. Another common accident is to get a foot stuck between two steps.



Open step Close step

Handrails should be placed at both sides, with pre-defined dimensions and shapes (according to the local building code). Distance from the wall should never be too large, because a limb could get stuck between the wall and the handrail. The correct shape and height of the handrail should be designed for both adults and children older than 5 years.

Stairs should always have a good lighting. Bad lighting can lead to a considerable increase in the number of stair-related accidents.

d) Combination of design attitudes which can increase the risk of an accident

The design of stairs that includes doors at the bottom, without providing for a landing area, can increase the risk of a more dangerous accident. For example, a stone flooring stair, which is polished and has a glass door at the bottom is much more dangerous than a carpet stair with a landing area and a wooden door at the bottom. In the first case, the most common mechanism of injury – fall – combines with two other mechanisms of injury – striking against the door and cuts because of the glass. The situation increases the risk of a more serious accident and the possible impacts on the victim are stronger.

The design of glass stairs or stone stairs with no handrail increases the risk of an accident. Wrongly dimensioned handrails can also make the risk higher.

Playing rooms and areas positioned close to stairs and not on the ground level increase the risk of an accident. The ideal location for a playing room is close to the place where the adults who attend the children stay most of the time, usually the living room.
Special care should be taken when positioning the playing room or area close to the kitchen or when it has a direct exit to outside. As I mentioned before, the kitchen is an attraction to the child and a room full of hazards.

Doors to the kitchen and outside doors (especially with direct access to swimming pools) should be monitored at all times. As was reported before, some American states' building codes require the use of an alarm on the door that leads to the pool. This is a practice that should be applied world- wide.

5 CONCLUSIONS

A child depends on an adult, especially between 0 and 5 years. It is the age when they are fully dependent on an adult to shape their personality and to live in a healthy environment. An accident at this time not only has an impact on the child's development but also on his family's structure. Parents sometimes may be have to stay at home with the child when the accident has strong sequelae, affecting the family income and the company where the parents used to work.

According to the World Health Organization, building standards have been identified as possible areas of action for the prevention of domestic accidents in all EU countries. Some of them are described below:

- Design of a hazard certificate: dwellings can be made safer by assessing the hazards they may contain and by creating incentives to remove them.

- Guidance for drafting a housing manual: to try to influence the behavior of inhabitants in order to decrease the risk of accidental injuries

- Issuing material to support information campaigns

- Identifying a strategy for research

- Promoting the use of economic instruments

- Involving constructors and other building industry professionals to encourage the practice of safe building elements in residences.

The propositions of the WHO project are challenging, because the actual building standards and legislation do not cooperate with the action fields proposed.

Domestic accidents represent over 60% of unintentional injuries to children between 0 and 4 years. They cause losses of thousands of lives and production losses in a given country. Domestic accidents, especially in children, are considered more than ever a potential and unattended field of action of governments, the industry and all citizens.

Europe and the United States already woke up to the dimension of the problem. More and more actions to prevent home accidents in the elderly are being included into governmental programs and technological research. But the statistics show that at least as many children (0 to 4) as the elderly suffer accidents at home.

The United Kingdom and the United States are developing programs to reduce the accident statistics, which should serve as examples for the world at large. The Austrian Institut Sicher Leben estimates that one child's life could be saved every 3 minutes in Europe if preventive actions were taken.

To reduce injury numbers, a range of studies on the main causes of injuries and main hazards inside homes have to be made. To date, only few countries have a reliable database with specific information on domestic accidents, listing the hazards that caused the injury, the precise location of the accident and objects involved.

On the strength of the collected data, a risk assessment of every hazard inside the domestic environment could be proposed. The intention is to give architects, contractors and other interested persons (parents) a tool to identify the degree of risk inside every room type, to point out potential hazards and to define the need and time of an action.

The weighting system created to fit the risk assessment table intends to give a rating for the main hazards inside each room type in a dwelling. It comprises three categories which were at this point judged to be sufficient to analyze the risk levels

– likelihood of an accident, impact on the child, and identifying and solving the problem.

After analyzing a case study, some efficient measures and technology for preventing domestic accidents were suggested.
Architects and contractors have the obligation to take part in these prevention programs, because they are responsible for planning and building the environments which people will live in. Those professionals are not only responsible for providing shelters for people, but rather for creating a healthy and safe living environment.

This responsibility makes new design and building concepts necessary, the main objective being a healthy and safe living environment without barriers, where everyone, in all stages of life, must feel comfortable and safe.

The risk assessment design guideline has the aim to contribute to the collection of statistics on accidents inside residences and to promote their prevention. It should avail itself as an easy and useful tool in analyzing domestic risks for architects, constructors and parents. Its use could extend to help create new building standards and new legislation aimed at preventing accidents in small children.

Architects have to be aware of their responsibility and capacity to contribute to this field, and this work should be the first step to integrate more professionals into the fight against the alarming rates of domestic accidents. Let’s remember, accidents will always happen, but a majority of them can be avoided. I think we can certainly agree that living in a safe and healthy environment is the right of every human being.

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8 ABBREVIATIONS

ANEC: European Association for the Coordination of Consumer Representation in Standarisation

CEHAPE . Children's Environment and Health Action Plan for Europe

CPSC : Consumer Product Safety , USA

ECOHEIS . Housing safety and accidents indicator

EHLASS . European Home and Leisure Accident Surveillance System

EISS: National electronic injury surveillance system

ENHIS . Indicator house accidents – traffic accidents

HASS: Home Accident Surveillance System

IDB . International Database

ISTAT: Italian National Institute of Statistics

LARES . Large analysis and review of European housing and health status

NAMCS: National Ambulatory Medical Care Survey

NCHS: American National Center for Health Statistics

NHAMCS: National Hospital Ambulatory Medical care Survey

NHIS: National Health Interview Survey

NVSS: National Vital Statistics System

HUD: Department of house and urban development

ICARIS: Sponsored Injury Control and Risk Survey

WHO: World Health Organization