A Study of Forecasting Methods for Misuse Accidents at Consumer Products to Promote Product Safety

消費生活用製品の製品安全推進のための誤使用事故予見方法に関する研究

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Chapter 1

Introduction

This chapter talks about the background of the study, reasons and based on that the purpose of this study.

1.1 BACKGROUND

In our daily life, we are using different types of consumer products that people buy for their own use at homes, workplaces, etc. However, the accidents while using those consumer products keep occurring. Each year, millions of injuries and thousands of fatalities could be attributed to consumer products [Rider et al, 2000; Gagg, 2005].

According to statistical study has been made by National Institute of Technology and Evaluation (NITE), from 2009 to 2011, 11,037 accidents cases when using consumer products were reported. The following Fig-1 shows the classification of the 11,037 accidents based on the cause of the accident, the cause for 59% of the accidents were the product itself, for 22% of the accidents the cause was not from the product, and the cause for the other 19% accidents were classified as unknown [NITE, 2013].

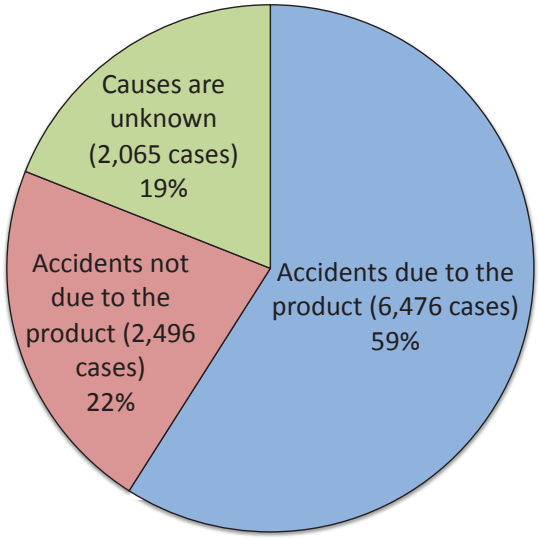

Fig-1: Accidents categorized by their cause
(it was referred to NITE to make this figure [NITE,2013])

In the 22% that the product was not the cause, 1569 accidents were because of user misuse. From the total number of accidents of 11.037, 122 accidents led to death tragedy [NITE, 2013]. Fig-2 shows the classification of the 122 accidents that led to death tragedy based on the cause of the accident.

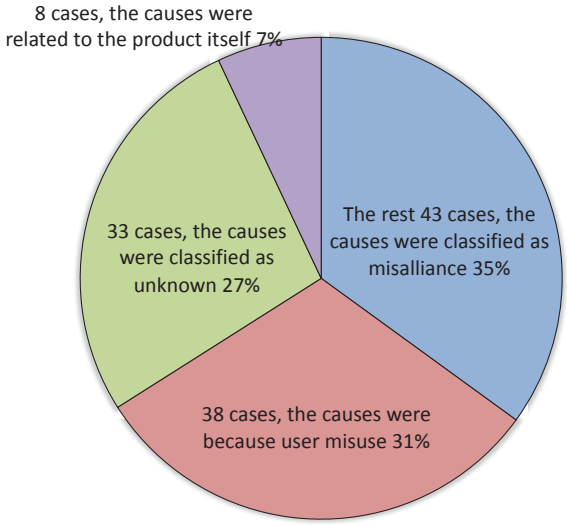

Fig-2: Accidents that led to death tragedy categorized by their cause
(it was referred to NITE to make this figure, [NITE, 2013])

The categories of causes that are shown in Fig-2 are:

- 38 cases, around 31%, the causes were because user misuse
- 33 cases, around 27%, the causes were classified as unknown
- 8 cases, around 7%, the causes were related to the product itself
- The rest 43 cases, around 35%, the causes were classified as misalliance

The causes are clear in two categories, user misuse and product. The number of cases in user misuse is more than four times the number in product category, the focus in this study is in the user misuse accidents. Manufacturers of consumer product, have been trying to assess the risks at their products during the development of the products. They often use risk assessment processes and methods from industrial fields.

1.2 RISK ASSESSMENT PROCESSES AND METHODS FOR INDUSTRIAL PRODUCTS

1.2.1 Risk assessment processes

Risks must be identified, evaluated, and controlled to prevent accidents from occurring [Bamber, 1986]. There are several risk assessment processes offered from ISO (Organization for Standardization) or IEC (International Electrotechnical Commission), for example:

- ISO/IEC guide51: 2014 Safety aspect – Guidelines for their inclusion in standards
- ISO 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction [ISO, 2010]
- ISO 10377:2013 Consumer product safety – Guidelines for suppliers [ISO, 2013]
- IEC 62366-1:2015 Medical devices – Part 1: Application of usability engineering to medical devices [IEC, 2015]

Each of them has risk assessment process, but the basic idea is the same as the process of ISO/IEC guide51 shown in Fig-3 [ISO/IEC, 2014]

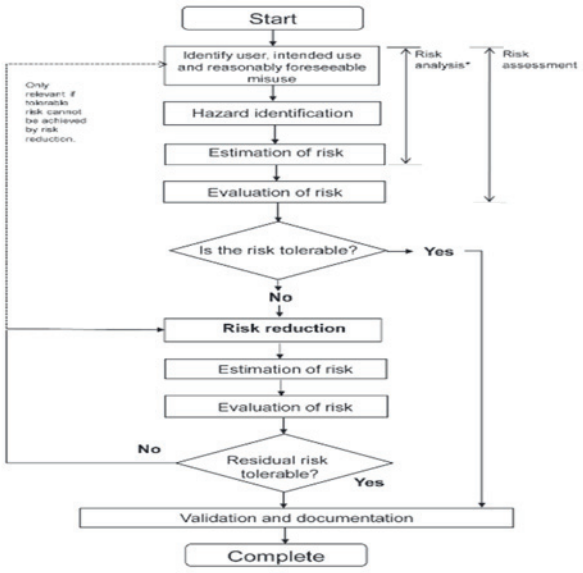

Fig-3: ISO/IEC guide51 risk assessment process

Here is a closer look at the definitions of items in ISO/IEC guide51:

- Definition of intended use and reasonable foreseeable misuse:

  Intended use here, refers to the use of product according to the information provided by the manufacturers or suppliers of the product targeted. Reasonable foreseeable misuse, refers to the use of the product in a way not intended by the manufacturers or suppliers of the product

- Hazard identification:

  Looking for the different types of hazards that are the potential source of harm, harm refers to injury or damage to people or environment

- Estimation & evaluation of risk:

  Looking for the combination of the probability of harm occurrence and the severity of that harm, then evaluating the found risk to see whether it is tolerated or not

- Risk reduction:

  Looking at intolerable risks, by trying to avoid them or reduce their risk level by developing some countermeasures. After that, one more time the step of estimation and evaluation will be conducted, if the found risk level was reduced into tolerable level, the process goes through validation and documentation step, if not there are two paths:

  - First path: is to go through the risk reduction step again and look for other countermeasures
  - Second path: if the risk level can't be reduced by the risk reduction step, the process returns again to the first step, definition of intended use and reasonable foreseeable misuse step

1.2.2 Promoting ideas for risk assessment processes

1-OKA triangle

OKA triangle proposed by Mr. Shuuichiro OKA, the idea is often taken at consumer product safety business, gives a classification for the types of misuse accidents and divides them into three categories as follows [NITE, 2005]:

- Normal use: using the product according to the way that manufacturers specified
- Foreseeable misuse: this category represents the cases where the misuse case is foreseeable to the manufacturers of the products
- Unreasonable use: at this category we are taking about using the product in a non-common sense way

Fig-4 shows the three categories of OKA triangle. It argues that manufacturers have an obligation to try their best to find countermeasures for accidents even for the unreasonable use.

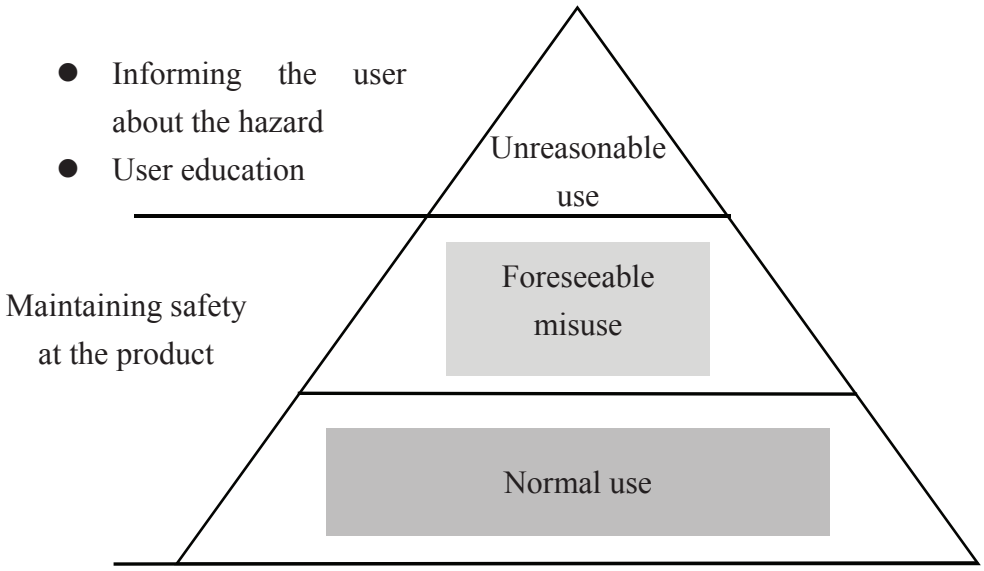

Fig-4: The three categories of OKA triangle

2-Hazard lists

Hazard lists, precisely obvious hazard in this study, are used to help in identifying different hazards at a certain system or product like for example OSHA (U.S. Department of Labor, Occupational Safety and Health Administration) 3071 Job Hazard Analysis (2002) Appendix 2 "Common Hazards and Descriptions" and ISO 12100 (Safety of Machinery-General Principles for Design-Risk Assessment and Risk Reduction) [OSHA, 2002].

3-Risk and risk matrixes

Risks are estimated and evaluated as mentioned in the example of ISO/IEC guide51, by looking for the combination of the probability of harm occurrence and the severity of that harm. To help in estimating and evaluating risks values from a certain hazard at a certain system or product risk matrixes are used, the higher risk values will be blacked by taking some countermeasures and the low risk values could be ignored, examples of risk matrixes tools are ANSI B11 matrix shown in table-10 and R-map [Matsumoto, 2016]. Risk matrixes usually have two dimensions, one represents severity and the other represents frequency. Severity dimension usually has several levels, starts from fatal level to the no-injury level. Frequency also has several levels, usually starts from frequent occurrence level to the unthinkable level. The intersection between the two dimensions forms blocks (cells) each one them represents a certain level of risk.

1.3 RISK ASSESSMENT METHODS

For industrial purpose, some risk assessment methods were developed based on

ISO/IEC guide51 risk assessment process that was mentioned in section 1.2. Here are two typical examples of risk assessment methods, that were adapted from industrial field to be applied on consumer products for safety aspects.

1.3.1 Be-safe (Behavioural Safety) method

Previously known as the Potential Human Error Audit [Simpson, 1994; Rachel & Sarah, 1998], it was developed by ergonomists at British Coal as a mean of targeting accident prevention initiatives. In industry it has a good level of success, as an example for that was in one coal mine where it helped in reducing accident rate by 80% [Simpson, 1994; Rachel & Sarah, 1998].

Be-safe method, is essentially an integrated set of ergonomics-based procedures (analysis techniques, check lists and questionnaires) to enable a person to identify systematically the potential for human error in a specific job, operation or system [Ergonomics and Safety Management Unit, 1995; Simpson et al, 1997; Rachel & Sarah, 1998].

Here is a closer look on Be-safe method, there are three main parts:

- Scenarios of use: the characteristics of the targeted users, environment of use, and description about the targeted products should be gathered to write the scenarios of using the products targeted.
- Analysis: there are two types of analysis, the ergonomic audit, instructional and behavioural audit. For the ergonomic audit, it is about looking at all design features of the product targeted that could predispose human errors when the product is

used according to its intended fashion. For the instructional and behavioural audit, it is about attempting to identify all factors individual or social that could predispose violations when the product is used.

- Action: at this step actions plan against the found human error and violation cases should be taken. There are two types of action plans, short-term action plan and long-term action plan. A prioritization process, should be applied to both types of action plans to see where are the parts that must be handled as fast as possible.

Fig-5 shows the main parts of Be-safe method

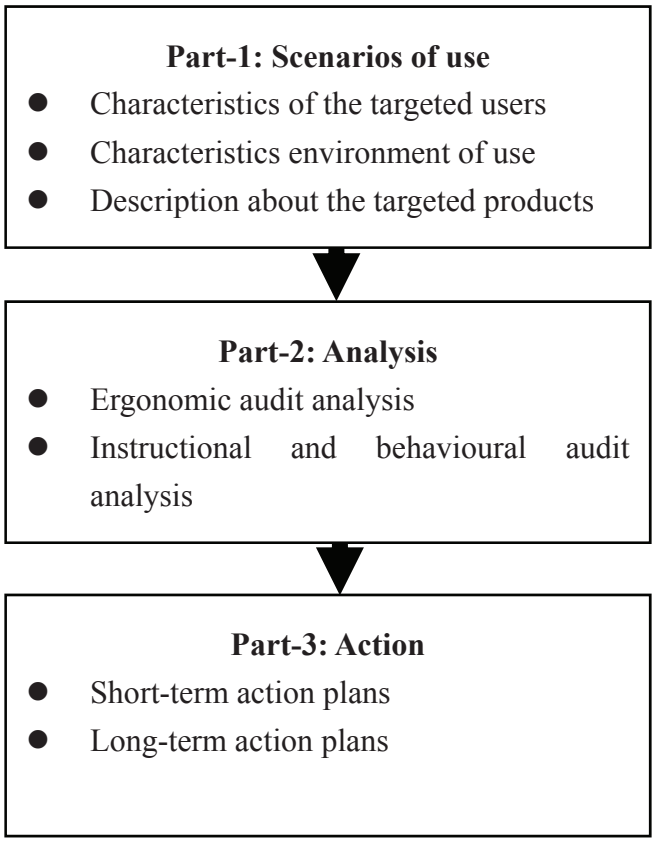

Fig-5: The main parts in Be-safe method

Be-safe could be related to or reflected on ISO/IEC guide51 process, the following

points show that:

- The scenarios in Be-safe could be related to identify user, intended use and foreseeable misuse in ISO/IEC guide51 process. For example, the scenario in Be-safe looks for the characteristics of targeted users, which reflects the part of identifying the user in ISO/IEC guide51 process
- For analysis in Be-safe, it could be related to hazard identification in ISO/IEC process. For example, the analysis in Be-safe looks for human errors and their causes from ergonomic perspective and also for instruction violations when using the product, in ISO/IEC guide51 process hazard identification looks for the hazards in the reasonably foreseeable misuse

[Rachel & Sarah, 1998] published a paper about adapting Be-safe method and applying it on consumer products (Slides, playground equipment) and they concluded to that Be-safe method, could help structuring the safety evaluation of the product that could help in developing the appropriate countermeasures to reduce risks in the products targeted. However, unlike industry field where user and environment are known and specified, consumer products have a wide range of users with different backgrounds and intuitions, the environment is remote which makes safety management for designers very challenging also environment could vary depending on the user.

1.3.2 FMEA (Failure Mode and Effect Analysis) method

It is a well-known method for finding potential failure modes and then prioritizes actions to reduce the risk of those failures. It was originally developed for the U.S. Military [MIL-STD-1629A, 1980], and the failures were classified according to their

impact on mission success and personnel/equipment safety [Clifton & Ericson, 2005]. After that it was used for space product development then in automobile industry [Clifton & Ericson, 2005]. The main parts of FMEA is shown in an FMEA sheet in table-1.

Table-1: the main parts of FMEA

Item or task list	Failure mode	Causal factors	Risk from failure	Countermeasures

Here is a closer look on FMEA method, the main parts that compose FMEA are as follows:

- Item or task list: in this part the components of the product targeted or the tasks that should be followed when using the product targeted should be listed, for task list they should be written in order.
- Failure mode: this part shows the possible failures that could occur at the components or tasks when using the product targeted, for finding these failures historical data, experiences, testing, and so on could be used. Some components or tasks could have more than one failure mode, all of them should be listed
- Causal factors: this part is about the possible causes of failures, there could be more than one cause for a certain failure, all of them should be listed
- Risk from failure: this part is about estimating the risk from a certain failure in case of occurring, at this part the failure frequency of occurring and the severity

of the failure should be estimated, the risk is presented in a form of a matrix between the frequency and the severity, the overlap between them represents the risk level

- Countermeasures: at this part the found risks should be checked to see if there are countermeasures to prevent them from occurring or not, of course the high-risk failures are better to be handled first

FMEA was also adapted in medical fields, for the purpose of finding different troubles and their causes while conducting medical activities and treatments, the main parts that compose FMEA are almost the same to what was mentioned previously and there is version of FMEA called (HFMEA, Health care FMEA) [Tanaka, 2002].

For FMEA in medical field, instead of looking for tasks that should be followed when using the product targeted, here the work flow or process of medical activates and treatments that target the patient will be looked at, to see what failure modes could occur and their causes [Iida, Kanauchi, Yanagawa,2014]. It should be mentioned also that, there are other versions of FMEA beside medical FMEA like design FMEA, product FMEA, process FMEA, and systems FMEA [Lynne, 2008]. For example, process FMEA was suggested to be used in the early stages of manufacturing process, like stages of product planning and designing to predict and prevent in advance the occurrence of problems related to product quality [Hanamura & Hirose, 2008]. Even in software product development, FMEA was proposed to be used to identify failure modes of system behaviors for software intensive systems [Nakanishi et al, 2012].

FMEA could be related to or reflected on ISO/IEC guide51 process, for example the part of risk, as we can see in FMEA there is a part handles risks from failure modes to find the tolerable risks, low risks, and the risks that should be eliminated, high risks. This is a direct reflection for the part of risks in ISO/IEC process

As Be-safe method, there was an attempt to adapt FMEA from industrial fields and apply it on consumer products, [Masuda, Iwase & Suzuki, 1999] tried to modify FMEA for reliability and safety analysis for consumer products. According to them hazardous factors exist at the interaction between the human (user or people exist around) and equipment (product targeted), frequency and amount of consequences induced by such factors are affected by their environment. The three elements (user, equipment and environment) were included in FMEA process to analysis user actions and trying to find human errors in that actions. However, they did not talk about the external influences from the surrounding environment for example or interfaces from other people near the user of the product in their modified FMEA.

[Clifton & Ericson, 2005] addressed 22 industrial methods like FMEA, FTA (Fault Tree Analysis) and other methods; they referred to them as hazard analysis techniques. In their book, they talked about the advantages and disadvantages in such methods, two of the most repeated disadvantages were: the possibility of becoming complex and time consuming, also the need for some training and practical experience. For FMEA they mentioned that it provides limited examination of external influences and interfaces.

1.4 CONSUMER PRODUCTS DEFINITION & CATEGORIES

1.4.1 Consumer products definition

The definition according to METI (Ministry of Economic, Trade and Industry in Japan) states that, consumer products are generally the products that consumers use for their daily life needs and buy them from ordinary markets [METI, 2017]. In general, consumer products serve to protect, support, and/or replace particular activities or extend consumer capabilities and ultimately improve quality of life [Kanis, 1998]

1.4.2 Consumer products categories

There is no specific standardized categorization for consumer products. However, it is possible to look at consumer products as there are two categories, software products like personal computer application software, and others consumer products that are tangible thing with physical form. Fig-6 shows these two categories.

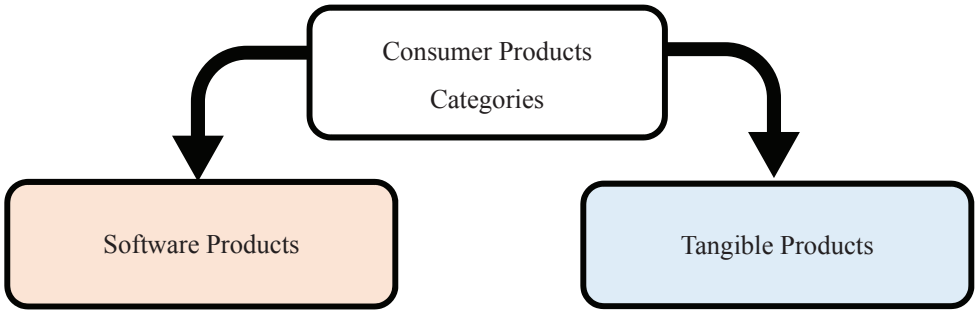

Fig-6: Consumer products categories

1.5 RELATION AND DEFINITIONS OF SAFETY AND HAZARD

1.5.1 Relation between safety and hazard

Safety and hazard terms are related to each other, for example in the field of systems

like automobiles, traffic systems, and other large systems the key to system safety and effective risk assessment is the identification and mitigation of hazards [Clifton & Ericson, 2005], such a way of looking at the relation between safety and hazard could be generalized to different fields like consumer products field as we have seen in ISO/IEC guide51, identifying the hazards then trying to reduce the risks from those hazards in order to promote safety level at the targeted product. A successful consumer product, will facilitate a balance between exposing the consumer to an acceptable level of risk and depriving the consumer of useful services and features [Hecht, 2003].

1.5.2 Safety definition

According to dictionaries like Oxford and Longman, safety in general defined as the condition of being safe and protected from danger, harm, risk, and injury. In the field of industry and systems MIL-STD-882D, standard issued from U.S Department of Defense (DoD) [Clifton & Ericson, 2005], mentioned in its definition of system safety that system safety is applied to achieve acceptable mishap risk. Accident could refer to a mishap or unwanted event which is not expected or designed by the victim [John, 1990], in consumer product field the victim could be the user of the product. To enhance the safety the hazard should be removed, controlled and reduced to the level that is insufficient to cause harm [Sanders and McCormick, 1993; Clark and Lehto, 2006].

1.5.3 Hazard definition

According to dictionaries like Oxford and Longman, hazard in general defined as potential danger that may cause accident or problem. In the field of industry and systems MIL-STD-882D states that the hazard is defined as follows: “any real or

potential condition that can cause injury, illness, or death to personal; damage or loss of system, equipment or property; or damage to the environment" [Clifton & Ericson, 2005]. Another definition from the U.S Army in their standard (Army AR 385-16) states that hazard is "a condition that is a prerequisite for an accident" [Clifton & Ericson, 2005]. As was seen in ISO/IEC guide51, hazard is defined as the source of harm, from the mentioned definitions it is obvious that hazard is a condition that should be eliminated to ensure safety use of system or product, the more hazard is controlled and mitigated the more safety level will increase. Now the definition of safety and hazard were introduced, let us see some international standards that include aspects like product safety and hazard identification in their process. ISO/IEC guide51 was introduced in some detail in section 1.2, other standards will be introduced here.

- ISO 45001: it is related to occupational health and safety management system (OH&S). The purpose is to enable organizations to improve their OH&S performance to prevent injury and ill-health. The standard helps in finding hazards and risks related to OH&S in a certain organization [ISO, 2018]
- Embedded System Development Quality Reference (ESQR): it is a reference issued by both Software Engineering Center (SEC) and Information-technology Promotion Agency (IPA) in Japan. The aim from it is to give a kind of guidance related to quantitative quality management to people engaged in embedded software development. It includes hazards identification and evaluation to such type of systems [IPA/SEC, 2010]
- IEC 61508: functional safety standard issued by International Electrotechnical Commission (IEC), mainly focuses on electronics. It treats the hazards that related to such systems or equipment to increase safety level at them [IEC, 2015]

By referring again to Fig-6, software category could be covered by standards like ESQR and they are out of scope in this study. For the tangible consumer products category in Fig-6, they are handled by industrial risk assessment standards, processes, and methods, this is the category targeted in this study and it is shown in Fig-7.

An investigation for different reported accidents when using the targeted consumer products in this study was conducted, to understand the details of the accidents and what kind of problems stand behind their occurrence.

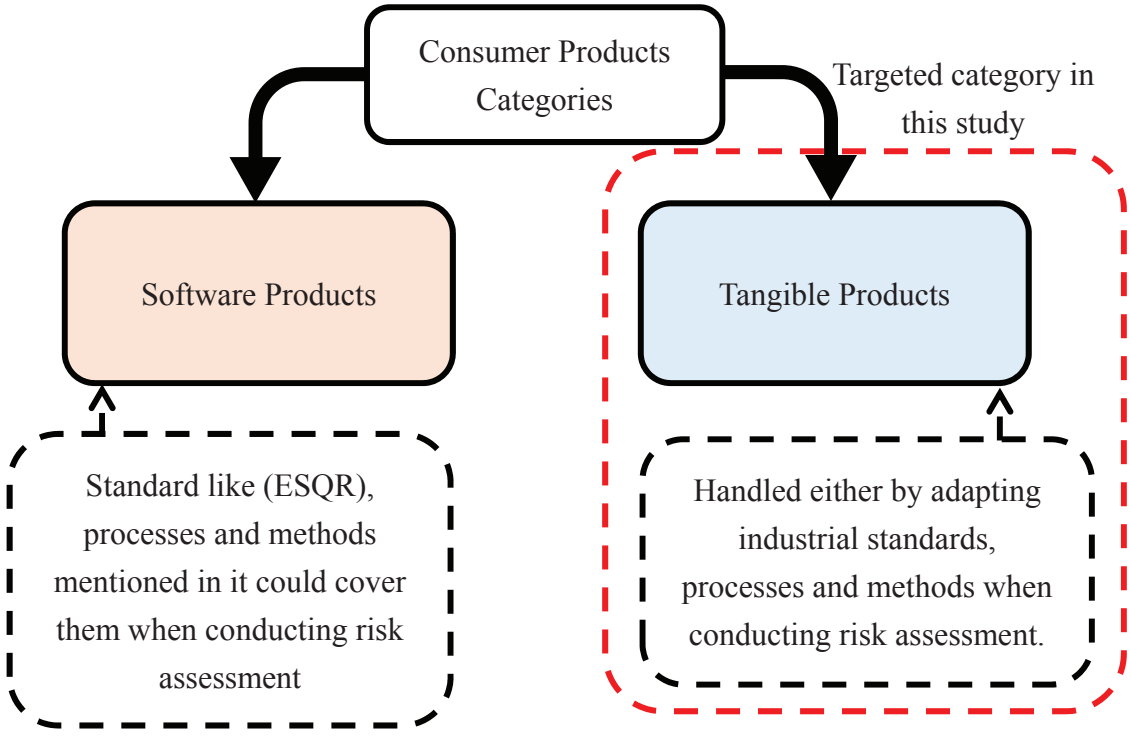

Fig-7: Targeted consumer products category in this study

1.6 ACCIDENT CASES AT CONSUMER PRODUCTS

From the definitions of hazard and accident at ISO/IEC guide51, [Clifton & Ericson, 2005] and other resources it possible to state the next equation, No Hazard No Accident. In the case of being unable or missing discovering and identifying the different types of

hazards at the products targeted accidents will occur.

To see what kind of problems, stand behind accidents occurrence, around 80 accidents cases while using consumer product, that were reported from both National Institute of Technology and Evaluation (NITE) and Consumer Product Safety Association (CPSA) from the period of 2005 to 2010 were reviewed in this study.

When reviewing, answering questions like (what stands behind accidents when using consumer products?) to understand the relation between hazard and accident, to see how the hazard leads to accident occurrence, was conducted.

It was found out in this study after reviewing the reported accidents that accidents come from two types of hazards, obvious hazards and hidden hazards. Table-2 shows the features of these two types.

Table-2: the features of obvious hazards and hidden hazards

	Obvious hazards	Hidden hazards
Features	● Contained in the product design like electrical, chemical, etc. Usually found in hazard check lists ● When the user interacts with them the accidents occur	● Product seem almost safe does not have any contained hazard ● When a deviation from the appropriate usage occurs, it could lead to accidents occurrence

In the following two sub-sections, first some examples are introduced to show both the obvious hazards and hidden hazards in real cases from the field. Then there is a discussion for these examples in terms of the features mentioned in table-2.

1.6.1 Examples from the reported accidents

(1) Accidents from obvious hazards:

a) A case of cuts accidents when using electric mixer: National Consumer Affairs Center of Japan, 2009 / 8 / 6.

- The consumer product is: electric mixer
- The accident: cuts and injuries due to the sudden rolling of the cutter inside the mixer regardless the existence of safety switch

b) A case of causing allergic reaction, skin reaction, when using a desk-mat: a case has been reported from National Institute of Technology and Evaluation (NITE), 2006 / 12 / 13, No. 73.

- The consumer product is: desk-mat that is used to cover desks at offices
- The accident: an allergic problem to the user skin because of some chemical interaction between the desk-mat components and the user skin

c) A case has been reported from National Institute of Technology and Evaluation (NITE), 2006 / 11 / 15, No. 72.

- The consumer product is: electric heater with a remote control
- The accident: the electric heater got switched on by another product remote control and resulted in fire accident

(2) Accidents from hidden hazards

a) A case of falling of movable closet: National Consumer Affairs Center of Japan, 2010 / 12 / 21.

- The consumer product is: movable closet
- The accident: falling of the closet while moving it by the user

b) A case of children bicycle chair: National Consumer Affairs Center of Japan, 2009 / 6 / 4

- The consumer product is: children bicycle chair that gets attached to the back seat of bicycle
- The accident: falling of both the chair and the child on the ground

c) A case of falling from small stepladder: National Consumer Affairs Center of Japan, 2007 / 5 / 9

- The consumer product is: small stepladder
- The accident: the falling from the small stepladder on the ground

1.6.2 A discussion about the examples from the reported accidents

In the above accidents cases, the first three were from obvious hazards. Such accidents could be possible (feasible) to be forecasted with using hazard list to check every hazard by the traditional risk assessment method. However, sometimes it could be difficult for the manufacturers to forecast many different possible (feasible) accidents because of the workload, the increase of the workload could lead to the increase of mistakes when doing a certain work [Guy, 2011] like when conducting risk assessment

as an example. Also, the absence of tools or methods that help to imagine and forecast as many as possible of such possible (feasible) accidents is another issue.

The consumer products usually have very specific purposes or functions [Bonner, 2001]. However, they may be used in unintended ways [Van Veen et al, 2001] or not in the appropriate way. For the other three products, they seem almost safe because they do not have any obvious hazards yet accidents occurred because of not following the appropriate usage. The hazard is hidden in those accidents that makes it difficult for the manufacturers to discover them in traditional risk assessment way; it seems different tools or methods that could help them to discover such hazards are needed.

1.7 CONSUMER PRODUCTS MANUFACTURERS AND INDUSTRIAL RISK ASSESSMENT PROCESSES AND METHODS

1.7.1 Consumer product manufacturers state

In consumer products field, according to a survey were conducted by Consumer Product Safety Association (CPSA) in 2002 [CPSA, 2002], about the way to forecast misuse accidents the majority of consumer products manufacturers relay on their experience for forecasting the misuse accidents. The following three points seem to be the reasons for that:

- Workload on risk assessment processes and methods: for example, at the risk assessment steps from ISO / IEC 51 guide, the process requires after forecasting all possible misuse cases at the targeted product to check each one of them to identify the risk level caused by the hazards contained in the targeted product. By such

process, low harm risks under acceptable level of risks would be evaluated as well as the high-risks, therefore this would lead to time consuming and increase of workload, which as a result could lead to miss evaluating some of high-risks. [Clifton & Ericson, 2005; Guy, 2011]

- Characteristics of consumer products: The traditional risk assessment process and methods are mainly used for industrial machines, where the varieties of use cases are rather limited. On the other hand, consumer products have totally the opposite; a huge variety of use cases, [Rachel & Sarah, 1998] have mentioned such a thing in their work. [Waldemar, Marcelo & Neville, 2011] also mentioned that the existed methods are more oriented toward the machine more than the user of the machine
- Characteristics of consumer products manufacturers: as most manufacturers of consumer products are rather small and professions of product safety are not always employed. Therefore, those who have little knowledge about risk assessment may conduct risk assessment, but the traditional risk assessment process is difficult for them

1.7.2 Problems when applying risk assessment processes and methods on consumer products

From what was mentioned above we can see the following problems:

- The complexity and time consumption (workload) problem: Manufacturers of consumer products, tend to depend on their own experience to avoid workload of conducting risk assessment according to certain processes and methods, here we have a total dependence on a person experience without the use of systematic process or method, such experience could betrayed a person

especially in the case of having a total new product with no history in the market, relaying only on personal abilities or experience could increase the chances of fail to forecast some accidents. Even in the case of succeeding in forecasting the accidents, the possibility it was just merely a good coincidence should not be overlooked.

- The need for training or practical experience in industrial risk assessment: as was mentioned, most manufacturers of consumer products are rather small and professions of product safety are not always employed. This could lead again to the use of just personal experience gained from the field or even not paying that much of attention to the important of conducting risk assessment, the results for that could be tragedy accidents as mentioned in section 1.1.
- The variety of users and environment: in the industrial fields the users and environment are specific and known unlike consumer products, this could explain the reasons of missing to forecast some accidents due to the absence of a comprehensive view to the user of the product targeted and the environment that the product targeted will be used at.
- Some methods like FMEA are machine oriented: this could explain the absence of looking at the external influences or surrounding circumstances, which as a result could lead to miss forecasting some accidents from them

1.8 THE PURPOSE OF THE STUDY

Based on the equation No Hazard No Accident and from the problems mentioned previously about the current industrial risk assessment processes and methods, the study

purpose is designing and developing two risk assessment method that:

- Help in discovering as many as possible of the different obvious and hidden hazards that stand behind accidents
- Help in Forecasting as many as possible accidents when using consumer products in a comprehensive way that covers most of the circumstances around the product targeted
- Help in reducing the workload when being used
- Does not required long training sessions or acquiring certain skills

1.9 THE TARGETED FIELD FORM THIS STUDY

The targeted people in this study are the manufacturers of consumer products, especially those who may have some difficulty in conducting a risk assessment either because the absence of experts about risk assessment or the short of hands in the number of employs. People are in contact with consumer products in a daily base, so to avoid or at least minimize accidents occurrence rate as much as possible, supporting the manufacturers of consumer products is a must thing to do. One way to do that is by providing them with a systematic risk assessment processes and methods include the five points that was mentioned above in the purpose of this study section. Additionally, for consumers in Japan for example, the Basic Consumer ACT in Japan law gives them some rights when using the consumer products and the first right is the insurance of safety when using a certain consumer product [Mimura, 2008]. Also, in the U.S, the worry about the hazards from consumer products resulted in the improvement of new consumer product safety act [Rider et al, 2009; Waldemar, Marcelo & Neville, 2011].

This could also increase the motivation to design and develop risk assessment methods target mainly the consumer products.

1.10 THE STRUCTURE OF THE STUDY THESIS

This study aims to design and develop two risk assessment methods, AMWAR (Analysis Method of the Worst Accidents Reasons) that targets obvious hazards and AMDHH (Analysis Method to Discover Hidden Hazards) that targets hidden hazards. Chapter 2 is about the study method. Chapter 3 is dedicated to AMWAR (Analysis Method of the Worst Accidents Reasons), the method is explained in detail. Chapter 4 is about the main case study that was conducted with AMWAR and the results found after the case study then the discussion and interpretation of those results. Chapter 5 is dedicated to AMDHH (Analysis Method to Discover Hidden Hazards). Chapter 6 is about the case study that was conducted with AMDHH and the results found after the case study then the discussion and interpretation of those results. The final chapter, Chapter 7 is an overall general discussion about the study, the view to the future based on the outputs from the study, and a final conclusion. Fig-8 shows the thesis general structure.

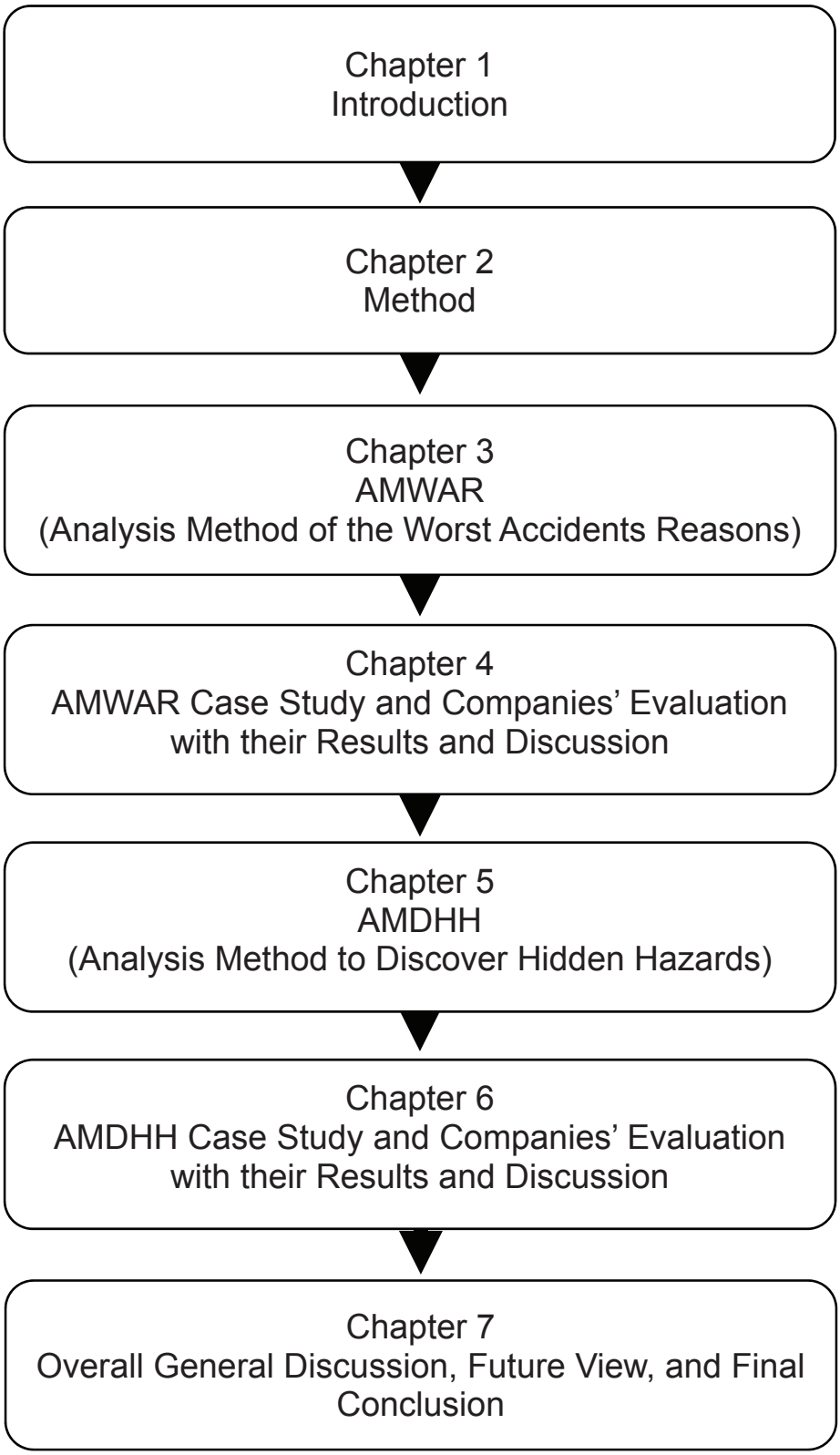

Fig-8: Flowchart shows the general structure of the thesis

Chapter 2

Method

This chapter talks about the method that was used to develop both AMWAR and AMDHH and also introduces the terminologies of this study.

2.1 PURPOSE OF THE METHODS

As mentioned in Chapter 1 section 1.5, the purpose of this study, the methods designed and developed in this study, is as follows:

- Help in discovering as many as possible of the different obvious and hidden hazards that stand behind accidents
- Help in Forecasting as many as possible accidents when using consumer products in a comprehensive way that covers most of the circumstances around the product targeted
- Help in reducing the workload when being used
- Does not required long training sessions or acquiring certain skills

This chapter gives a general view about, what was done to accomplish the purpose of this study and also provides a list of the terminologies in this study.

2.2 DESIGNING AND DEVELOPING AMWAR (ANALYSIS METHOD OF THE WORST ACCIDENTS REASONS)

The purpose of designing and developing AMWAR is, to handle the accidents in the case of obvious hazards. For workload reduction, in the case of obvious hazards our work reached to an assumption that, if the focus gets shifted toward the worst accidents

that have high-risk levels only the workload when conducting risk assessment is highly expected to reduce. AMWAR consists of steps looking for obvious hazards, the worst accidents, direct reasons for worst accidents, scenarios behind direct accidents, and checking countermeasures against scenarios. A type of analysis called Sabotage analysis [Sawaguchi, 2007] that is used to find how an accident could occur was adapted to find the direct reasons of the worst accidents. Sets of guidewords were designed to increase the number and the variety in the scenarios behind direct reasons of the worst accidents. Further explanation is provided in Chapter 3 about AMWAR and each step in it.

For obvious hazards like electric, mechanical, chemical, etc., instead of starting from scratch and creating a new list of obvious hazards to use them to check if the product targeted have those hazards or not, OSHA list was utilized because hazards and their characteristics were written in an easy way to understand, beside OSHA list contains many obvious hazards that are also included in ISO 12100. The detail of the list is provided in Chapter 3.

In order to verify that AMWAR could help achieving the purpose of this study, a case study and evaluation from experts in the field of risk assessment were planned and conducted, case study part was conducted by using AMWAR by people with little experience of risk assessment, the evaluation part was conducted by companies and specialists with high level experience in product safety to evaluate the method based on evaluation sheet submitted to them. Further explanation is provided in Chapter 4 about the case study and the evaluation from experts in the field of risk assessment.

2.3 METHOD OF DESIGNING AND DEVELOPING AMWAR

To build AMWAR the following steps were followed:

- ***Designing the AMWAR process:*** during the designing process many reported accident case were investigated and several drafts were designed, tested, and modified until reaching to the finalized shape
- ***Conducting a case study:*** the case study was conducted on the finalized shape to see for what degree AMWAR met the requirements
- ***Evaluating AMWAR:*** evaluation was conducted on the finalized shape to see for what degree AMWAR could meet the requirements, the evaluation was conducted by companies and researchers with high level experience in product safety

2.4 DESIGNING AND DEVELOPING AMDHH (ANALYSIS METHOD TO DISCOVER HIDDEN HAZARDS)

The purpose of designing and developing AMDHH is to handle the accidents in the case of hidden hazards.

For hidden hazards, the way of discovering cannot depend on just checklist like obvious hazards because hidden hazards are hidden in the usage of the product. Since it was noticed that there is a direct relation between accidents and not following the product usage appropriately, an assumption was built that the hidden hazard is the deviation from the appropriate usage, this assumption was verified by using PDPC (Process Decision Program Charts). The try helped us to reach to a conclusion that

deviation that causes accidents is a potential hidden hazard and further detail about this conclusion also is provided in Chapter 5.

AMDHH consists of steps looking for the appropriate usage of the product targeted, the deviations from the appropriate usage, deviations that could lead to accidents occurrence, evaluating the accidents, and checking countermeasures against accidents. Like AMWAR sets of guidewords were designed but in the case of AMDHH to increase the number and the variety in the found deviations from the appropriate usage. Further explanation is provided in Chapter 5 about AMDHH and each step in it.

In order to verify that AMDHH could help achieving the purpose of this study, a case study and evaluation from experts in the field of risk assessment were planned and conducted, case study part was conducted by using AMDHH by people with little experience of risk assessment, the evaluation part was conducted by companies and specialists with high level experience in product safety to evaluate the method based on evaluation sheet submitted to them. Further explanation is provided in Chapter 6 about the case study and the evaluation from experts in the field of risk assessment.

For risk evaluation part in AMDHH and countermeasures checking in both AMWAR and AMDHH, since they require a high knowledge about risk assessment, the design of the product, and the need to actual data from the field about the product they were not executed in the part of case study.

2.5 METHOD OF DESIGNING AND DEVELOPING AMDHH

To build AMDHH the following steps were followed:

- ***Designing the AMDHH process:*** during the designing process it was referred to AMWAR especially in the part of building a comprehensive method, the items in AMWAR model and the guidewords. Several drafts were designed, tested, and modified until reaching the finalized shape
- ***Conducting a case study:*** the case study was conducted on the finalized shape to see for what degree AMDHH met the requirements
- ***Evaluating AMDHH:*** evaluation was conducted on the finalized shape to see for what degree AMDHH could meet the requirements, the evaluation was conducted by companies and researchers with high level experience in product safety

2.6 TERMINOLOGIES

The important terminologies in this study are determined as follows:

1. Appropriate usage

It refers to expressing the context of use items in term of appropriateness to conduct the tasks set when using the product.

2. Deviation

It refers to deviating from the appropriate usage, if a certain deviation cause accident then it is a hidden hazard.

3. Direct reasons of worst accident

It refers to the main reasons behind worst accidents occurrence in the case of obvious

hazards.

4. Direct reasons scenarios

It refers to the sequence of events that lead to the existence of direct reasons in the case of obvious hazard accidents, the source of the scenarios is the context of use five items.

5. Guidewords

It refers to a set of words and it is used to help in imagining more direct reason scenarios in the case of obvious hazards accidents and also imagining more deviations from the appropriate usage in the case of hidden hazards. Each item from the five items of the context of use has its own guidewords set.

6. Hidden hazard

As was mentioned in table-2, it refers to a type of hazards that results from deviating from the appropriate usage of a certain product. Product in the case of hidden hazards seems almost safe and does not have any contained hazard.

7. Obvious hazard

As was mentioned in table-2, it refers to a type of hazards that contained in the product designed and usually found in hazard check lists. When the user interacts with them the accidents occur. Chemical hazard and electrical hazard were introduced as examples of obvious hazards in Chapter 1 sub-section 1.7.1.

8. Obvious hazard list

It refers to a list contains different obvious hazards. The idea of using list is a common tool in risk assessment like OSHA list, ISO list, or other hazard check lists.

9. Sabotage analysis

A type of analysis looks for how to cause accident [Sawaguchi, 2007], it was used in this study to find direct reasons behind worst accidents in the case of obvious hazards,

more about sabotage analysis in Chapter 3 sub-section-3.3.1

10. Tasks set

It refers to the steps that ensure using a certain product safely. The user have to use the product according to the tasks set.

11. The context of use five items

It refers to five items: user (the three types), environment, time of use, method of use, and relation with surrounding other products. In the case of mismatching between them and the product targeted accident can occur.

12. Workload

The time and effort used to conduct a certain task, in the context of this study, the time and effort used when conducting risk assessment.

13. Worst accidents

It refers to the accidents with high-risks that could occur in the case of obvious hazards.

Chapter 3

AMWAR
(Analysis Method of the Worst Accidents Reasons)

This chapter talks about the developed AMWAR method, its basic concepts and techniques that used in AMWAR, the logic behind AMWAR and the finalized shape.

3.1 PURPOSE OF AMWAR

AMWAR (Analysis Method of the Worst Accidents Reasons) targets obvious hazards, it should help in forecasting many accidents, help in reducing the workload when conducting risk assessment, be a suitable risk assessment method for the field of consumer products that do not required special skills from manufacturers of consumer products or long training sessions.

3.2 BASIC CONCEPTS & TECHNIQUES USED IN AMWAR

3.2.1 Basic concept

As was mentioned, current risk assessment processes and methods look for all accidents from the very low-risk to the very high-risk accidents. Such a work could increase the workload because of investigating cases that almost cause no harm to the user. In AMWAR, the suggestion is to shift the focus toward high-risk accidents only to reduce the workload. First finding the obvious hazards then the worst accidents, high-risk accidents, from those obvious hazards. Countermeasures are taken to avoid the worst accidents occurrence, figuring how those accidents occur is essential to check countermeasures, here Sabotage analysis [Sawaguchi, 2007]

was adapted to identify the direct reasons of the worst accidents.

3.2.2 Sabotage analysis

Sabotage analysis is a type of analysis has been developed at the Soviet Union for security purpose to face the terrorist attacks [Sawaguchi, 2007]. Its concept is to think how to cause the accident, based on that countermeasures would be checked against those accidents. The point here is thinking how to cause worst accident to occur, this way of thinking will keep stimulating the person mind to identify more reasons, besides help in identifying rare cases that could be difficult to get identified. Sabotage analysis was used in several other fields; at industrial safety, it was introduced as a suggestion to the field of radioisotopes radiation facilities [Kato, 2009]. It was also used at the field of expressway traffic control system to find how accidents occur at such systems and based on that developing countermeasures to prevent accidents occurrence [Sawaguchi & Nakahara, 2014], also at the field of information technology (IT) to predict different kinds or risks that could occur in the digital world [Sawaguchi, 2015]. At consumer product field, it was also introduced to show the effectiveness of adapting such analysis technique when evaluating safety aspects at consumer products [Bonkobara, Altiyare, & Komatsubara, 2012].

3.3 BUILDING AND FINALIZING AMWAR

3.3.1 Building AMWAR

From the beginning, the strategy for building AMWAR was establishing assumptions then putting those assumptions in a form of process, testing this process, and based on the results revising AMWAR until reaching the finalized version. The following three points show the logic of AMWAR and what distinguish it from the current risk assessment processes and methods.

- No Hazard No Accident, if a certain type of hazards was first identified all accidents from that type of hazard could be found. The current processes and methods as ISO/IEC Guide 51 shown in Fig-3 do the opposite, start by looking first at possible misuse cases or scenarios of use then after that looking for hazards in them. Which way would be easier to conduct, looking for a certain type of hazards, then looking for the accidents that could come from them, or finding possible misuse cases or scenarios of use and then looking for hazards in them in general without specifying a certain type. Different types of hazards could require different ways or methods for handling them, not paying attention to the types of hazards and treating them all as just hazards could lead to miss some hazards, the result could be cases like what mentioned in Chapter 1 sub-section 1.4.1. Looking for a certain type of hazards at first could help in ensuring covering accidents from that type comprehensively.

  Regarding the obvious hazards type, as was mentioned in Chapter 1 sub-section 1.4.1, obvious hazards are contained in the design of the product

like electric, mechanical, chemical and so on, they could be identified easily with using checklist. What was mentioned about looking for a certain type of hazards then the accidents that come from it suits the case of obvious hazards, using a list to identify obvious hazards then looking for accidents from them. This could help in covering accidents from obvious hazards comprehensively.

- Regarding the workload issue, it was mentioned in section 3.3, shifting the focus toward worst accidents could help in reducing the workload. Current risk assessment processes and methods handle all risks from low-risks to high-risks. Also, in section 3.3, it was mentioned that the idea of Sabotage analysis [Sawaguchi, 2007] was adapted to find the direct reasons of the worst accidents, thinking how to cause the accident is a new way in the field of consumer products safety.

- Regarding the situations and circumstances around the product targeted, they are mentioned in the current processes and methods in a way or other, but without providing a systematic way to determine them, covering them comprehensively, and their relationship with the possible accidents. For example, in ISO/IEC guide51 the talk is mainly about the user without referring to other items that also formulate the situations and circumstances around the product targeted beside user item. If those items were not covered as much as possible in a comprehensive way, it might lead to conduct ineffective or insufficient risk assessment, the result of such a thing obviously

could be accident occurrence.

What should be covered in a comprehensive way here is the relationship between such items and the accidents, some may argue that direct reasons are enough but those direct reasons do not come out of nowhere, there is something leads to the existence of the direct reasons, could be the user of the product targeted, the environment, the time of use, or even other items. Capturing the scenarios that show how such items lead to direct reasons existence could help in seeing the relationship between the situations and circumstances around the product targeted and the worst accidents.

The result would be a more comprehensive risk assessment and it would facilitate checking countermeasures against worst accidents, the more the background of an accident is understood the more checking countermeasures would be effective and easier.

3.3.2 Finalized AMWAR

The final shape of AMWAR is as follows:

1. Identify the obvious hazards in the targeted product
2. Identify the worst accidents that could result from the obvious hazards
3. Identify the direct reasons of the worst accidents
4. Find out the scenarios that cause the direct reasons

5. Check the countermeasures of the targeted product

Step-1: Identify the obvious hazards in the targeted product

This step is related to identifying obvious hazards in the product targeted. As was mentioned in Chapter 2 sub-section 2.2.1 OSHA hazard list was utilized to make obvious hazards list. The list is shown in table-3

Table-3: The obvious hazards list

Hazard	**Hazard definition**
Chemical (Toxic)	Absorption through the skin, inhalation, or through the blood stream that causes illness, disease, or death. [OSHA, 2002]
Chemical (Flammable)	Exposing to a heat ignition source that results in combustion. [OSHA, 2002]
Chemical (Corrosive)	A chemical that when it comes into contact with skin, metal, or other materials damages them. Acids and bases are examples of corrosives. [OSHA, 2002]
Explosion (Chemical Reaction)	Materials like gases that classified as explosive materials. [OSHA, 2002]
Explosion (Over Pressurization)	Sudden and violent release of a large amount of gas/energy due to a significant pressure difference such as rupture in a boiler. [OSHA, 2002]
Electrical (Shock/Short Circuit)	Contact with exposed conductors or a device such as when a metal ladder comes into contact with power lines. [OSHA, 2002]
Electrical (Fire)	Use of electrical power that results in electrical overheating or arcing to the point of combustion or ignition of flammables, or electrical component

	damage. [OSHA, 2002]
Electrical (Static/ESD)	The moving or rubbing of wool, nylon, and other materials that create an excess or deficiency of electrons on the surface of material that discharges (spark) to the ground resulting in the ignition of flammables or damage to electronics or the body's nervous system. [OSHA, 2002]
Electrical (Loss of Power)	Safety-critical equipment failure as a result of loss of power. [OSHA, 2002]
Ergonomics (Strain)	Damage of tissue due to overexertion (strains and sprains) or repetitive motion. [OSHA, 2002]
Ergonomics (Human Error)	A system design, procedure, or equipment that is error-provocative. (A switch goes up to turn something off). [OSHA, 2002]
Ergonomics (Carelessness)	Injuries result from personal actions like for example: falling of nail or screwdriver on body parts. [OSHA, 2002]
Ergonomics (Fall, Slip, Trip)	Conditions that result in falling, slipping, tripping such as slippery floors, poor housekeeping, uneven walking surfaces, exposed ledges, etc. [OSHA, 2002]
Fire/Heat	Temperatures that can cause burns to the skin or damage to other organs. Fires require a heat source, fuel, and oxygen. [OSHA, 2002]
Mechanical (Vibration/ Fatigue)	Vibration that can cause damage to nerve endings, or material fatigue that results in a safety-critical failure. Examples are abraded slings and ropes, weakened hoses and belts. [OSHA, 2002]
Mechanical Failure	Typically occurs when devices exceed designed capacity or are inadequately maintained. [OSHA, 2002]
Mechanical (injuries/damages to	Skin, muscle, or body part exposed to crushing, caught-between, cutting, tearing, shearing items. Other equipment exposed to damages. [OSHA, 2002]

other machines)	
Noise	Noise levels (>85 dBA 8 hr TWA) that result in hearing damage or inability to communicate safety-critical information. [OSHA, 2002]
Radiation (Ionizing)	Alpha, Beta, Gamma, neutral particles, and X-rays that cause injury (tissue damage) by ionization of cellular components. [OSHA, 2002]
Radiation (Non-Ionizing)	Ultraviolet, visible light, infrared, and microwaves that cause injury to tissue by thermal or photochemical means. [OSHA, 2002]
Struck By (Mass Acceleration)	Accelerated mass that strikes the body causing injury or death. Examples are falling objects and projectiles. [OSHA, 2002]
Temperature Extreme (Heat/Cold)	Temperatures that result in heat stress, exhaustion, or metabolic slow down such as hypothermia. [OSHA, 2002]

Step-2: Identify the worst accidents that could result from the obvious hazards

Each found obvious hazard in the product targeted will be checked to see what is the worst accident that could occur form that obvious hazard, there could be more than one worst accident to a certain obvious hazard. As a reminder, focusing on the worst accidents with high-risks is the key to reduce workload. This step will be done by trying to imagine and generate freely as many as possible worst accidents.

Step-3: Identify the direct reasons of the worst accidents

Sabotage analysis will be used to identify the direct reasons of the worst accidents by answering the question (how to cause the worst accident to occur?), again it will be done by trying to imagine and generate freely as many as possible direct reasons.

Step-4: Find out the scenarios that cause the direct reasons

The term scenario means a set of events occur and lead at the end to a certain result, in this case the result is the direct reasons. To ensure having a comprehensive covering for the direct reasons, sets of guidewords that were designed and developed to help in imagining as many as possible of direct reasons scenarios, the explanation about them is written in detail in sub-section 3.4.3.

Step-5: Check the countermeasures of the targeted product

All scenarios would be checked to see the countermeasures at the product targeted. To conduct step5, technical knowledge about the safety conditions of the targeted product is required.

3.3.3 Developing guidewords model for AMWAR

There is a variety in the circumstances and contexts of use when using a product, the way of interacting with the product could differ depending on the circumstances and contexts of use [Chamorro-Koc et al, 2009]. [Komatsubara, 2009] investigated consumer products accident cases to propose a model that shows the items that surround a product, in case of mismatch between them and the product targeted accidents will occur. The model was developed based on the human errors model besides analyzing different reported accidents cases, 8 items were found that must be investigated in order to forecast mismatch scenarios to prevent accident from occurring. The items that build the model are as follows:

- Primary user (U): the person who will use the product targeted
- Secondary user & Seatmate user (family F): people who help or happen to be close to the primary user when he / she uses the product targeted
- Method of use (M): The way of using the product targeted
- Environment of use (E): The place that the product targeted is used
- Relationship (R): relationship with other products around the product targeted
- Time of use (T): The longtime of being in contact with the product and the frequency of usage
- Usage Restriction (software S): rules and instruction when using the product targeted
- Supporting Stuff (liveware L): providers of the product targeted, maintenance stuff

In the case of mismatching, for example using the product from inappropriate primary user, or using the product in inappropriate environment accident can occur.

The main items of the model in the context of use are five items and they are: user (the three types), environment, time of use, method of use, and relation with surrounding other products. For liveware, it does not always exist especially in the case of very simple consumer products, for software they could be grouped with the method of use. Now the five items have become the following:

- The user: who has connection with the targeted product, which has three types: the primary, the secondary [JoAnn.T and Janice. C, 1998], and the seatmate

- The environment: The place that the targeted product is used
- The time of use: The longtime of being in contact with the product and the frequency of usage
- The method of use: The way of using the targeted product
- The surrounding other products: The products that surround the targeted product and could give undesirable effects on the targeted product

A modified model that represents those five items is shown in Fig-9, the model shows the five items surround the product targeted that contained hazards (obvious hazards), the model named AMWAR model.

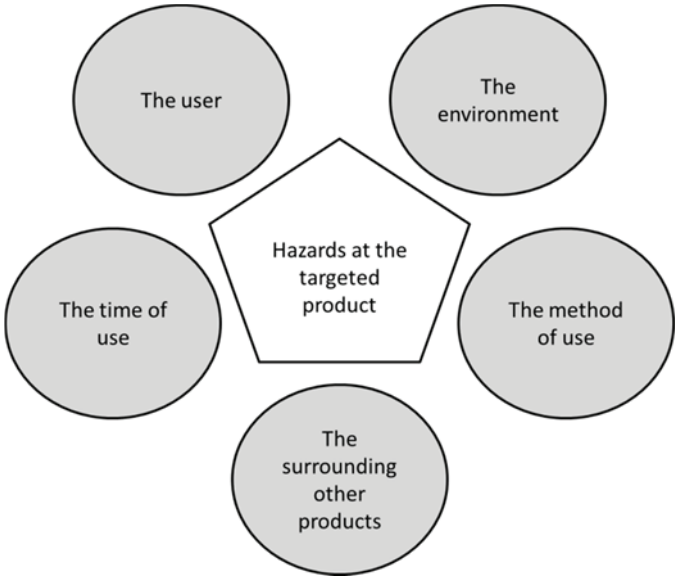

Fig-9: AMWAR modified model

Finding scenarios that show how those items could lead at the end to accident occurrence in a comprehensive way means finding as many as possible of those scenarios and in the same time having a variety in them

3.3.4 Developing the guidewords for AMWAR

The idea of using guidewords was used to help in imagining as many as possible scenarios. The guidewords for each item in Fig-9 were developed. The guidewords were designed by referring to HAZOP guidewords and ISO 9241-210 (Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems) [ISO 9241-210(E), 2010].

In chemical plants field there is a method called HAZOP (Hazard and Operability Analysis) [Trevor, 1999], sometimes called (What if) method. it is usually used to identify hazards and problems in chemical plants to prevent any effect on the efficiency of plants operation. It utilizes key guidewords and system diagrams to identify system hazards [Clifton & Ericson, 2005], the aim from them to stimulate the creative process of identifying hazards. Some example of HAZOP guidewords are as follows:

- More: A quantitative increase in the design intent occurs (e.g., Temperature or Pressure)
- Less: A quantitative decrease in the design intent occurs (e.g., Temperature or Pressure)
- Early: The timing is different from the intention, it indicates that a step is started early to the pre-determined time.
- Late: The opposite of Early
- Reverse: Logical opposite of the design intention occurs

For ISO 9241-210 (Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems) the human-center design model includes the following four parts:

- Understand & specify context of use
- Specify user requirements
- Produce design solutions to meet user requirements
- Evaluation design against requirements

The part about understand & specify context of use is about the characteristics of the users, tasks and organizational, technical and physical environment that define the context in which the system is used. The context of use shall include description about the following:

- The characteristics of the users: it is an information that includes knowledge, skill, experience, education, training, physical attributes, habits, preferences and capabilities about the user who would use the system or the product
- The goals of the users and the overall goals of the system: it is an information about the characteristics of tasks that can influence usability and accessibility, the frequency and duration of performance, and other characteristics related to the goal of the user and the overall goal of the system or product
- The environment(s) of the system: it is an information about the technical environment that includes the hardware, software, and materials. In addition to technical part other aspects of environment like the physical, social and cultural shall be described. The physical attributes include issues such as thermal

conditions, lighting, spatial layout and furniture. The social and cultural aspects of the environment include factors such as work practices, organizational structure and attitudes

The guidewords and their definitions for each item is as follows:

- User (primary, secondary, and seat mate) set is shown in table-4

Table-4: User guidewords set

Guidewords	Definition
Age	The targeted user of the product
Attitude	The targeted user attitude towards the product like for example nervousness when using the product
Knowledge	The necessary skills and knowledge when using the product
Mental state	The mental state when using the product like for example awareness
Physical state	The physical state when using the product like for example the existence of handicap, the physical strength

- Environment set is shown in table-5

Table-5: Environment guidewords set

Guidewords	Definition
Space	The place that the product will used at
Power source	The necessary energy sources to use the product
illumination	Illumination at the place when using the product
Atmosphere	Effecting the workplace atmosphere like for example the relation among the workers at the workplace

- The time of use set is shown in table-6

Table-6: The time of use guidewords set

Guidewords	Definition
Usage Duration	The length of time period when using the product during one time
Usage frequency	The number of times that the product is being used

- Method of use set is shown in table-7

Table-7: Method guidewords set

Guidewords	Definition
Too fast	Faster than the required speed to conduct a task when using the product
Too slow	Slower than the required speed to conduct a task when using the product
Too much	Excessiveness in physical power, number of usage, etc. when using the product
Little	Insufficient physical power, number of usage, etc. when using the product
Disorder	Tasks disorder when using the product
Jump	Jumping tasks when using the product
Save	The way of saving the product
Roughness	Handling the product in a rough way

- Surrounding other products set is shown in table-8

Table-8: Surrounding other products guidewords set

Guidewords	Definition
Switch on/off	Get switched on/off by the other surrounding products
Damage	Receiving a damage form the other surrounding products
Effect	Receiving an effect from the other surrounding products like for example electrical interference

3.4 SUMMARY OF THIS CHAPTER

In this chapter, Chapter 3, AMWAR was explained in detail, the next chapter, Chapter 4, is about the case study, the evaluation from experts in the field of risk assessment, and the outputs from both of them.

Chapter 4

AMWAR Case Study and Companies' Evaluation with their Results and Discussion

This chapter talks about the case study of applying AMWAR and the evaluation of AMWAR by expert in the field of consumer products safety.

4.1 CASE STUDY

4.1.1 The purpose of the case study

The purpose is to use of AMWAR by people with little experiences in risk assessment to see whether they could find scenarios that cause the worst accidents.

4.1.2 The method of the case study

An arrangement with 15 university students with little experience of risk assessment as participants was made. They were asked to proceed AMWAR individually with the targeted product given, with using the developed textbook for AMWAR. Only step-5, countermeasures checking, that needs expert people in the design of the targeted product to be conducted has been eliminated from the case study. Fig-10 shows the chosen targeted consumer product and its general specification; the electric drill with which the participants are familiar, and therefore they expected to be able to imagine the usage cases.

- Weight: about 1kg
- AC 100V
- Frequency: 50/60Hz
- Torque: 10.0 N · m
- Cord Length: Approx./1.5 m
- Maker: (Sankyo corporation)

Fig-10: The electric drill on the case

4.1.3 The results of case study

4.1.3.1 The Distribution of scenarios**:**

The results from all participants have been combined together; the contained hazards pointed out were 16, the worst accidents were 20, the direct reasons obtained were 129, and the direct reasons scenarios were 390. Table-9 shows a sample for the total result. Fig-11 shows the percentage per each item in AMWAR model from the total obtained number of scenarios from all participants.

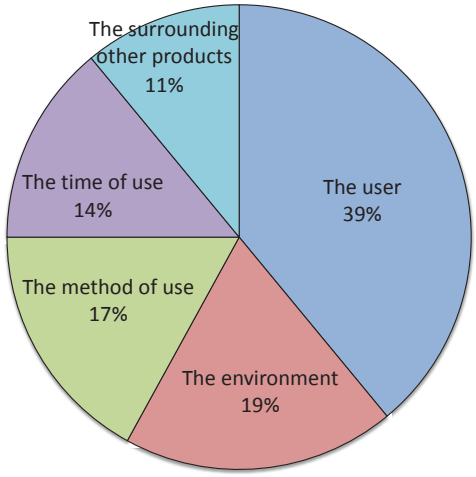

Fig-11: The percentage per each item in AMWAR model from the total obtained number of scenarios

4.1.3.2 Hazard identified:

Fig-12 shows the repetition rate of the hazards among all participants. From Fig-12, electric hazard (short circuit/ shock), electric hazards (fire), and the mechanical hazard, that are rather obvious at the electric drill, have high repetition rate than the less obvious hazards like the electric (static), electric (loss of power), struck by (mass acceleration), and temperature extreme (heat or cold).

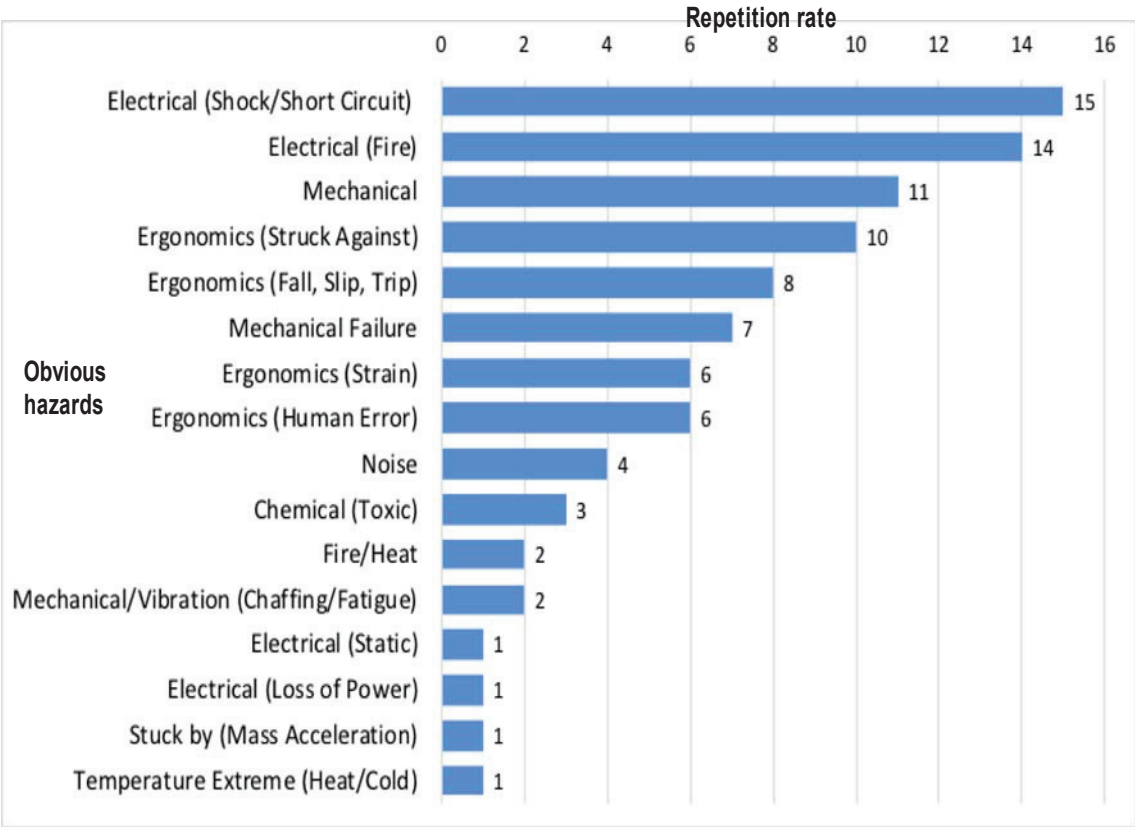

Fig-12: Contained obvious hazards types and their repetition rate

4.1.3.3 Found scenarios against time of case study conducting:

Fig-13 shows the amount of the forecasted scenarios against the time for each participant. The longest time was around 120 min with 53 scenarios; the shortest time was around 28 min with 21 scenarios.

Table-9: A sample for the total result from the case study

The contained hazards	The worst accidents	The direct reasons	The direct reasons scenarios
Electric (shock/short circuit)	Death or heavy burn due to electric shock	Rolling up the electric cord on the drill body	Not noticing the electric core while doing the work (Mental state)
		Touching the electric source by wet hand	Working in bad illuminated places (Illumination)
			Storing the drill in wet places (Storing)
Mechanical	Cuts or laceration	Touching the drill's blade while working	Pressing the switch by mistake while trying to change blade (Mental state)
			Colliding with other works during the work in small size places (Space size)
Chemical (toxic)	Harming the respiratory system	breathing harm gas	Putting the drill near products omit high heat that lead to melt the plastic cover the drill and producing harm gases (Damage)
Electric (fire)	Death or heavy burns	Using electric source while having accumulated dust on it	The ignorance of cleaning the electric sources from the accumulated dust (Educational background)

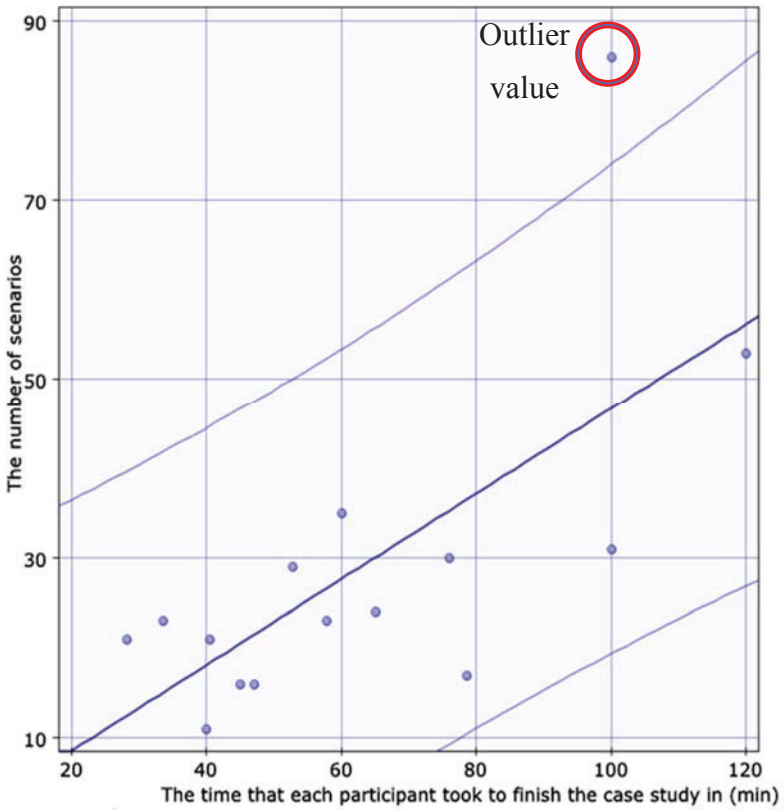

Fig-13: The time that each participant took to finish the case study (min) vs. scenarios number

4.1.4 The discussion of the results of case study

There were some nonsense scenarios that have been omitted from the total result; for example, intended actions to harm other people or even to harm the user him/herself that could be classified under illegal or crimes category not misuse category. However, since participants were imagining freely, nonsense scenarios are expected.

For the five items in Fig-11, it was found that the user item is the source of 39% of the scenarios; the user controls the other items and for that it makes sense that almost half of the scenarios come from the user item. On the other hand, the surrounding other

products item was the lowest in the number of scenarios by 11%. It is thought that the targeted electric drill was robust to get affected easily by the surrounding other products.

For Fig-12, as the electric drill is an electric and mechanical product, it makes sense that obvious hazards related to those two features appeared many times. The participants are familiar with the electric drill but on the other hand, they do not have enough technical knowledge about the electric drill design and so they seem not be able to notice less obvious hazards; this suggests that participants are required to have enough technical knowledge of the targeted product to conduct AMWAR, even if they have little experience of risk assessment.

Fig-13 of the relation between the number of scenarios and the time that each participant took to finish the work shows the increase of the number of scenarios with the increase in time (R=0.68). However, only one case is far from the line; that is an outlier value of 90% prediction interval. The explanation for this value is that the participant imagination ability is higher. If this value ignored, R=0.73. However, from another point of view, this could show that the enhancing of imagination ability would lead to more effective use of AMWAR.

In general, the participants managed to conduct the AMWAR; there was a variety in the direct reasons and the scenarios behind them despite the fact that they have little

experience in risk assessment. The enhancement of imagination ability will be the key issue to have the best possible results of AMWAR. Instead of imagining individual, doing that in groups may be better, as it could help in forecasting more scenarios and at the same time could help in omitting the repeated scenarios.

4.2 EVALUATION FROM COMPANIES

4.2.1 The purpose of the evaluation from companies

The purpose of the evaluation from companies was to obtain evaluation about AMWAR from people in charge of product safety based on their business experiences.

4.2.2 The method of the evaluation from companies

An evaluation sheet and AMWAR manual were distributed to safety management staff of quality assurance section and designers with product safety experience at their companies. It was also submitted to experts in product safety and to staff of insurance companies. They were asked to read the manual and the case study written in the manual, and based on that, they were asked to imagine or actually conduct AMWAR on their products. They were asked to participate voluntarily in the evaluation and any other kind of financial interest or benefit does not exist among the authors.

After that, they were asked to answer the evaluation sheet. The evaluation sheet includes a set of questions about, for example:

- The agreement or disagreement on the concept of AMWAR
- The agreement or disagreement on the ability of using AMWAR in the case of having little risk assessment experiences

The agreement or disagreement on the possibility of reducing the workload when doing risk assessment with AMWAR

4.2.3 The results of evaluation from companies

26 evaluation sheets were received; 10 sheets from designers of consumer products at large scale companies, 8 sheets from safety staff at large scale companies. 2 sheets from designers at small scale companies, 2 sheets from safety staff at small scale companies, 2 sheets from academic institutes, and 2 two sheets from insurance companies. The answers were reviewed and summarized in the following points:

1. The agreement or disagreement on the concept of AMWAR:

Fig-14 shows the number of people who agreed and not agreed with the concept of AMWAR. The agreement reasons were almost the same among all; as currently there is a tendency to blame the manufacturers even if the accidents are caused by rare case of misuse which includes violation, AMWAR could help finding these rare misuse cases by seeing how the user would use the product in real life. The disagreement was because AMWAR focuses only on high-risks accidents; therefore, it missed the recall from low harm accidents which could affect adversely the firm valuation.

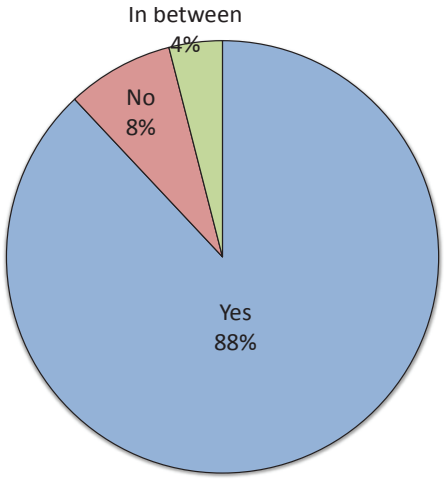

Fig-14: The agreement on AMWAR concept

2. Using AMWAR when having little experiences about risk assessment:

Around 62% of the evaluators think that AMWAR could help the people with little experiences in risk assessment. They say that finding out the check points for countermeasures has become easier. The disagreement on the other side was because that AMWAR sometimes needs to be mastered in order to use it effectively, especially for the use of guidewords.

3. The possibility to reduce the workload:

Around 63% think that AMWAR could reduce workload because AMWAR is focusing the attention only on the high-risks to eliminate the effort of looking on the low-risks. The disagreement was because that imagining the scenarios with guidewords is sometimes difficult and it may take time and efforts.

4. The helpfulness of AMWAR at the product manufacturing stages to check the safety aspects in the product:

For product planning, could be helpful for extracting harms in the targeted product and listing them or conducting risk assessment roughly on prototype product. For conceptual design, could be helpful for determining at which part of the design the risks exist and whether it could be avoided. For detailed design, could be helpful to avoid missing risks or hazards in the final stage of the design. However, this could be difficult because the final shape of the product has been finalized, so the range of changing the design of the product is limited. For the quality assurance, could be helpful as a check tool for insuring the safety aspect at the targeted product to see if there are missed risks that have not been identified at the previous stages.

5. The types of products that AMWAR is effective or not effective to be used:

They say that AMWAR could not be effective for the consumer products that are an extension from conventional (traditional) consumer products in the market, because the worst accidents patterns do not include that much of differences. However, it would be effective for totally newly developed consumer products because all risks have not been identified at the market field.

6. Other application of AMWAR:

As to other applications of AMWAR except risk assessment, a variety of opinions was obtained. The followings are the remarkable comments:

- AMWAR could be used for increasing the user awareness about the danger of violating the manual instructions by showing the users the scenarios and their

results. Also, it could be used as educational tool to increase the awareness about risk assessment for the companies' staff especially for the novice designers.

- AMWAR could be used for PL (product liability) insurance business. At such fields, especially smaller companies sometimes must pay a lot of insurance premium to cover accidents including low-risks, because they cannot focus only on the high-risks that need PL insurance essentially. But by using AMWAR, the insurance premium could be reduced because they can focus only on high-risks more accurately with achieving accountability for their customers.

7. The improvement points on AMWAR:

As AMWAR results depend on imagination, it was pointed that some guidance when imagining worst accidents, direct reasons and guidewords is better to be provided to increase the efficiency when using AMWAR. Another point is that the occurrence possibility of the scenarios should be assessed before checking the countermeasures to avoid checking the countermeasures against too rare scenarios.

4.2.4 The discussion of the results of evaluation from companies

The idea of using the concept of Sabotage Analysis, the core concept of AMWAR, was approved; AMWAR could be a helpful method to reduce workload and for the people with little experiences about risk assessment.

AMWAR seems to be effective for newly developed consumer products that contain

hazards especially with new products without accident history; in such cases forecasting as much as possible accident scenarios is highly desired. AMWAR could be used in most phases of the product manufacturing. Another point is that AMWAR has been suggested to be used for other applications as educational program. However, developing some guidance for practicing on how to use AMWAR effectively may be an important point that should be taking in consideration.

4.3 GENERAL DISCUSSION OF AMWAR BASED ON THE RESULTS OF CASE STUDY AND EVALUATION FROM COMPANIES

From the results of the case study and the companies' evaluation sheet, it was found that AMWAR could help the people with little experiences about risk assessment by reducing the workload, which is the advantage that the traditional risk assessment methods do not have. Moreover, several advantages of AMWAR were found; it could be used for some applications as educational tool. Because of the focus on the worst accidents, it could be used as a supporting tool with PL (product liability) business to reduce the amount of insurance premium or other risk assessment processes or methods.

As companies nowadays have begun paying attention even to rare or nonsense accident scenarios, AMWAR would help finding out them through imagining them with the guidewords developed. However, AMWAR seems to have several limits; AMWAR

does not include low-risks that may cause the problems of recalling. Another point is the imagination ability; enhancing imagination ability would be the key issue to help conducting AMWAR effectively.

4.4 SUMMARY OF THIS CHAPTER

In this chapter, Chapter 4, the case study and companies' evaluation of AMWAR were presented in detail. For the case study the results and the discussion of the results were presented, the same was for companies' evaluation. At the end a general conclusion from both the case study and the evaluation were presented.

Chapter 5

AMDHH
(Analysis Method to Discover Hidden Hazards)

This chapter talks about AMDHH method, its basic concepts and techniques that used in AMDHH, the logic behind AMDHH and the finalized shape.

5.1 PURPOSE OF AMDHH

AMDHH (Analysis Method to Discover Hidden Hazards) targets hidden hazards, it should help in discovering as many possible hidden hazards in order to cover as many as possible of their accidents, be a suitable risk assessment method for the field of consumer products that do not required special skills from manufacturers of consumer products or long training sessions.

5.2 BASIC CONCEPTS & TECHNIQUES USED IN AMDHH

5.2.1 Basic concept

Deviation is simply moving away from the appropriate way or usage of the product targeted, deviations that lead to accidents are potential hidden hazards, an assumption was established that expressing the appropriate usage then finding the deviations from it in a comprehensive way will ensure covering many hidden hazards. No Hazard No Accident, the accidents that come from hidden hazards, unlike the case of worst accident in AMWAR, are a mix of low and high risks accidents so conducting risk evaluation is necessary. Based on the result from risk evaluation the accidents that countermeasures should be taken against them will be determine.

5.2.2 PDPC method

The concept of PDPC (Process Decision Program Charts) is taken in AMDHH. It is a method developed in 1968 as a problem solving and decision making by Prof. J. Kondo [Yoshinobu, Toru, Ryoji, and Hiroyuki, 2007], it consists of a series of steps linked in sequences and the goal is to discover the different events obstacles likely to occur and deviate the original plan during progressing from the start point to the end point, there is also a type of PDPC where the path starts from the end point to the start point [the committee for developing QC tools, 1988; Yoshinobu, Toru, Ryoji, and Hiroyuki, 2007] . For safety purpose, it was used for marine accidents analysis [Tesuya, 1996].

5.3 BUILDING AND FINALIZING AMDHH

5.3.1 Building AMDHH

The strategy for building AMDHH is the same as AMWAR, establishing assumptions then putting those assumptions in a form of process, testing this process, and based on the results revising the method until reaching the finalized version. The following two points show the logic of AMWAR and what distinguish it from the current risk assessment processes and methods.

- The current risk assessment processes and methods as was mentioned in Chapter 3 sub-section 3.4.1 handle all hazard types together without distinguishing between those types, the different types of hazards could require different ways or methods for handling them. As a matter of fact, mixing hidden hazards with other types

when conducting risk assessment could reduce the chances of discovering hidden hazards because most of the attention could go toward types like obvious hazards that clear and could be noticed sometimes by just looking at the product. Providing a method focuses only on hidden hazards could help in ensuring covering accidents from them comprehensively.

- Regarding the situations and circumstances around the product targeted, as was mentioned in Chapter 3 sub-section 3.4.1 that the current processes and methods include in a way or other the situations or circumstances around the product targeted, but without providing a systematic way to determine them, covering them comprehensively, and their relationship with the possible accidents.

In the case of AMWAR, the scenarios that show the relationship between the items that formulate the situations and circumstances around the product targeted were under the scope to be identified, in the case of AMDHH the deviations will be under the scope. Deviation cannot occur out of nowhere, there is a user who could cause the deviation, the environment or the time of use that could also influence and lead to deviation occurrence, or even other items. Covering comprehensively how those items could cause deviations would lead to discovering many hidden hazards and the accidents they could cause. As a result, that will help in seeing the relationship between the situations and circumstances around the product targeted and the accidents.

5.3.2 Finalizing AMDHH

The final shape of AMWAR is as follows:

1. Writing the appropriate usage when conducting tasks set
2. Forecasting deviations from the appropriate usage
3. Finding the accidents in the deviations forecasted
4. Accidents risk evaluation
5. Checking the countermeasures state

Step-1 Writing the appropriate usage when conducting tasks set

To write the appropriate usage the tasks that shows how to use the product safely should be written first. If the task is conducted by the appropriate user, at the appropriate environment and so on, the product will be used safely, those items are the same item in the context of use that was in Chapter 3 Fig-9, in AMDHH they will be found in term of appropriateness as follows:

- User (two items): a primary user who conducts task appropriately and a secondary user who could help conducting task appropriately or receive the effect from the primary user who is appropriately conducting the task. For seat mate user in the case of hidden hazards it was treated as secondary user and that because during the several trails with AMDHH the results of secondary user and seat mate user were almost identical
- Environment: appropriate place for task conducting
- Time: appropriate time duration for conducting task and appropriate frequency of

usage of the targeted product

- Method: The appropriate way that the task is being conducted
- Other surrounding products: appropriate products that surround the targeted product when the task is being conducted, even the products that may come in contact

The answers for the above items does not always have to be unique. As long it ensures conducting the tasks set safely it is accepted.

Step-2 Forecasting deviations from appropriate usage

The deviations from the appropriate usage that cause accidents are potential hidden hazards so as many as possible number of deviations is desired, imagining and generating freely as many as possible deviation with guidewords approaches was used, the explanation about them is written in detail in sub-section 5.4.3.

Step-3 Finding accidents in the forecasted deviations

Accidents are found by investigating each deviation in each one of the context of use items, deviations that lead to an accident is a potential hidden hazard. There could be more than one accident per deviation.

Step-4 Accidents risk evaluation

After finding accidents, their risks will be evaluated by some risk matrix, for

example using ANSI B11 matrix. ANSI B11 matrix is a verbal-based evaluation, frequency of accidents occurrence and severity of accidents used to evaluate the risk level, both of them have four levels as shown below.

Frequency levels are as follows:

- Very Likely: the probability of accident occurrence when using the product targeted is very high
- Likely: the accident is likely to occur
- Unlikely: the accident probability is very low
- Remote: the probability of occurrence is almost zero

Severity levels are as follows:

- Catastrophic: accident lead to death tragedy
- Serious: accident lead to serious injuries that unrecoverable
- Moderate: accident lead injuries that recoverable
- Minor: accident could be handled with just first-aid treatment

The frequency and severity relation in ANSI B11 matrix is shown in table-10:

Step-5 Checking the countermeasures state

Based on the results of risk evaluation for each accident, countermeasures should be checked; in the case of their absence, they should be designed and taken.

Table-10: ANSI B11 risk matrix to evaluate the risks

Frequency	Severity			
	Catastrophic	Serious	Moderate	Minor
Very likely	High	High	High	Medium
Likely	High	High	Medium	Low
Unlikely	Medium	Medium	Low	Negligible
Remote	Low	Low	Negligible	Negligible

5.3.3 Developing the guidewords for AMDHH

In AMDHH to design and develop the sets of guidewords the same approach that was used with AMWAR was used again, referring to HAZOP guidewords and the way of applying them and also ISO 9241-210 (Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems). The only different between guidewords in AMWAR and AMDHH is, in the case AMWAR the guidewords itself and their definitions were separated but in the case of AMDHH they are mixed together in a form of sentence, it is just a different in shape to distinguish between them. The guidewords set for each item in the context of use is as follows:

- User set, for both primary and secondary user, is shown in table-11

Table-11: User (primary and secondary) guidewords set

Age (too young, too old)
Physical features (height, weight, physical strength, handicap state)
Mental state (tiredness, rashness)
Knowledge and experience (understanding the way of usage, having the necessary skills to use

the product)
Attitude and personality (attitude when using the product, habits, focus power)

- Environment set is shown in table-12

Table-12: Environment guidewords set

Physical conditions (direct effect on the product: vibration, temperature, humidity)
Effect on the mental state of the user (noise, atmosphere, illumination, bad smell, sense of touch)
Limitation on the use of the product (the floor, obstacles when moving the product)
Natural environment (the existence of bets, natural phenomena like weather)
Social conditions (congestion, local culture)

- The time of use set is shown in table-13

Table-13: The time of use guidewords set

Time slate: night, midnight, morning, afternoon, evening
Duration: too long, too short
Frequency: too many, very little

- Method of use set is shown in table-14

Table-14: Method of use guidewords set

Usage order (disorder, omitting, unnecessary extra actions)
Timing (too early, too late)
Operation means (roughness, insufficient power, excessive power, using inappropriate tools)
Usage speed (too fast, too slow)
Gesture when operating (inappropriate gesture)
The number of users (conducting the task from one person while it requires more than one person in the case of conducting)

- Surrounding other products set is shown in table-15

Table-15: Surrounding other products guidewords set

Attaching materials to the product (attaching other products, using with other products simultaneously, etc.)
Materials that the users attach to their body (clothes, protecting tools, etc.)
The existence of other products that give effect on the product（electrical interference, high temperature, etc.）

5.4 SUMMARY OF THIS CHAPTER

In this chapter, Chapter 5, AMDHH was explained in detail, the next chapter, Chapter 6, is about the case study, the evaluation from experts in the field of risk assessment, and the outputs from both of them.

Chapter 6

AMDHH Case Study and Companies' Evaluation with their Results and Discussion

This chapter talks about the case study of applying AMDHH and the evaluation of AMDHH by expert in the field of consumer products safety.

6.1 CASE STUDY

6.1.1 The purpose of the case study

The purpose of the case study is to see if people with little experiences in risk assessment could discover hidden hazards by using AMDHH.

6.1.2 The method of the case study

An Arrangement with 16 university students to participate in the case study was made. They were asked to proceed using the AMDHH process individually from step 1 to step 3. Step-4, risk evaluation. Step-5, countermeasures checking, needs expert people in the design of the targeted product to be conducted so participants were not asked to conduct them. Tasks set that formed from 10 tasks was provided in advance for them to ensure that they work on same tasks contents. Every participant has been asked to record the time that he/she took to finish the AMDHH experimental work.

Fig-15 shows the chosen targeted consumer product, a ladder, that the participants are familiar and, therefore, they are expected to be able to discover hidden hazards without specific knowledge of this product. Then they have been asked for a feedback on the easiness of understanding AMDHH concept and conducting the steps

- Height: approx. 100.5 cm
- Width: approx. 40 cm
- Depth: approx. 60 cm
- Weight: approx. 5.4kg
- Maker: IRIS OHYAMA Inc.

Fig-15: The ladder for the case study.

16 result sheets were obtained. Participants were asked to find appropriate usage, deviations, and the possible accidents from each deviation. Deviations that lead to accidents are the hidden hazards, for each result sheet the number of hidden hazards were counted at each task among the 10 tasks, after that how many times each discovered hidden hazard has been repeated among the 16 result sheets was counted.

6.1.3 The results of case study

6.1.3.1 The discovered hidden hazards:

Table-16 shows sample of one of the obtained results and it's for method item; the table shows the task, appropriate usage, deviations and possible accidents. 54 different types of hidden hazards have been discovered in the 10 tasks among all result sheets. Fig-16 shows their distribution over the five items. For the repetition number there were some high repetition numbers because there were 54 different hidden hazards and 10 tasks. The discovered hidden hazards and repetition rate for each item are shown in table -17 up to table-22.

Table-16: Example of the results obtained and it's for method item

Tasks set	Appropriate usage	Deviations	Possible accidents
Hold the edge of ladder and put your leg straight forward on ladder step one after another, while climbing watch your fee	Watching steps carefully while climbing	Not watching steps carefully while climbing (omitting)	Missing one's footing and falling from ladder on the ground
	Climbing at ease	Climbing in hurry (fast task conducting)	Getting one's leg injured from striking one's leg against ladder steps
	Putting foot straightly on step	Not putting foot straightly on step (bad balance)	Losing balance and falling from ladder on the ground

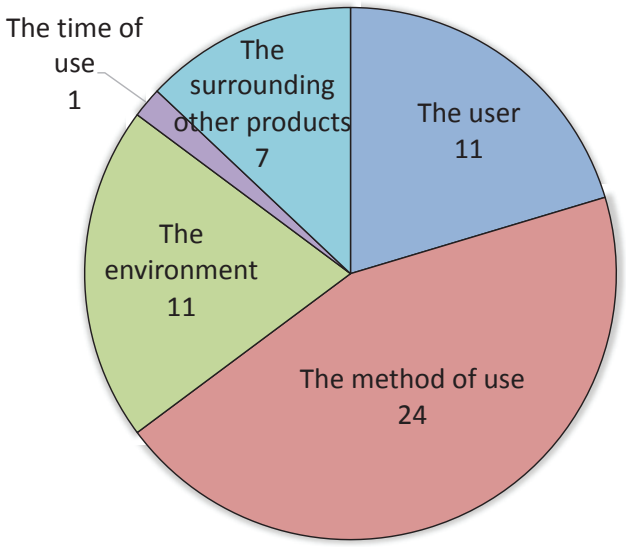

Fig-16: Hidden hazards distribution over the five items,
primary and secondary refers to user item

Table-17: Discovered hidden hazards and repetition rate for primary user item

Discovered hidden hazards	Repetition rate
Children who do not have the necessary physical strength to handle the ladder	112
Old people who do not have the necessary physical strength to handle the ladder	70
People with handicaps	43
Users who do works in rush	11
Overweight users	10
Rough or sloppy users	8
Too much physically or mentally tired users	6
Users with no experiences in using ladders	4

Table-18: Discovered hidden hazards and repetition rate for secondary user item

Discovered hidden hazards	Repetition rate
Children who do not have the necessary physical strength to support the ladder for primary user to climb or come down	74
People with handicaps	24
Old people who do not have the necessary physical strength to to support the ladder for primary user to climb or come down	17

Table-19: Discovered hidden hazards and repetition rate for environment item

Discovered hidden hazards	Repetition rate
Using the ladder in a dark place	112
Using the ladder in a crowded place	58

Using the ladder on non-flat surfaces	58
Using the ladder on wet surfaces	56
Using the ladder on beveled surfaces	54
Using the ladder on slippery surfaces	36
Using the ladder on places like stairs	15
Using the ladder in narrow spaces	13
Using the ladder on unstable surfaces	11
Using the ladder on muddy surfaces	7

Table-20: Discovered hidden hazards and repetition rate for time of use item

Discovered hidden hazards	Repetition rate
Using the ladder when it is dark	89
Staying for long time on the ladder	7

Table-21: Discovered hidden hazards and repetition rate for method item

Discovered hidden hazards	Repetition rate
Making either the ladder or body leaning	38
Climbing or coming down from the ladder without holding the ladder edge	37
Opening, climbing, coming down, folding the ladder in a hurry	33
Not paying attention to foot place when climbing or coming down from the ladder	32
Using to much force when handling the ladder	32

Jumping the ladder steps when climbing or coming down	31
Using the ladder with checking whether it is locked or not	21
Turning the foot sideways when placing them on the ladder steps	17
Handling the ladder with only one hand	14
Using the ladder by two users at the same time	9
Placing hands on inappropriate places when opening or folding the ladder	9
Sitting down on the ladder steps in a rough way	8
Not using the necessary force when handling the ladder	8
Opening or folding the ladder while hanging it above the ground	7
Looking aside while climbing or coming down from the ladder	5
Using the ladder before opening it completely	3
Trying to open or fold the ladder by pulling other parts of the ladder and not the lock ring	3
Pulling the ring of the ladder by using more than one finger	3
Trying to fold the ladder without pulling the ladder lock	2
Placing the foot on the step together at the same time	1
Letting off the ladder edge while climbing or coming down from the ladder	1
Shaking the ladder while climbing or coming down from it	1
Handling the ladder without using one's dominant hand	1
Not pulling the ladder ring in a straight direction when opening or folding	1

Table-22: Discovered hidden hazards and repetition rate for surrounding other products

item

Discovered hidden hazards	Repetition rate
Something gets the user distracted when using the ladder	63
Handling the ladder with slippery gloves or shoes	61
Having too many objects and things surrounding the ladder when using it	39
Putting some kind of flat cushions on the steps of the ladder and sitting on them	12
Using clothes that easily get caught in the ladder	11
Using clothes that make the move difficult when handling the ladder	4
Wearing more than one pair of gloves on the hands when handling the ladder	1

Here is the explanation of the discovered hidden hazards and repetition rate for each item:

- For the primary user: the use of products from small children who do not have physical abilities to use ladder was the highest repeated hidden hazard with repetition number of 112. On the other hand, lowest repeated of only 4 was having a little educational background or little experiences about using the ladder. For the secondary user: the support when using the ladder from small children who do not have physical abilities to support was the highest repeated hidden hazard with repetition number of 74. On the other hand, lowest repeated of only 17 was supporting from aged people.
- For the environment: the use of the product at places under low visibility was the

highest repeated hidden hazard with repetition number of 201. On the other hand, lowest repeated of only 7 were using the ladder at muddy places.

- For time: one hidden hazard, staying for too long time on the ladder with repetition number of only 7.
- For method: leaning too much from the primary user when using the ladder or making ladder itself lean too much was the highest repeated hidden hazard with repetition number of 38. On the other hand, lowest repeated of only 1 was not using one's dominant hand when using the ladder.
- For other surrounding products: the use of gloves or shoes that could cause sliding or falling from ladder was the highest repeated hidden hazard with repetition number of 61. On the other hand, lowest repeated of only 1 was wearing more than one pair of glove.

The majority of deviations from hidden hazards could cause fall accidents from the ladder or fall of the ladder on the primary user, the secondary user, or other people close to work spot. Only in time item, the hidden hazard, staying too long on the ladder, could cause some pain accidents to user's body especially the lower back of the body.

6.1.3.2 Found accidents against time of case study conducting:

The time that each participant took to finish the experiment has been measured. The total number of accidents that each participant has found has been calculated among the entire tasks set. Fig-17 shows the relation between the number of the accidents and the

time that each participant took to finish the work. It has the correlation factor R=0.59. The longest time was 130 min with 185 accidents, and the shortest time was 40 min with 40 accidents.

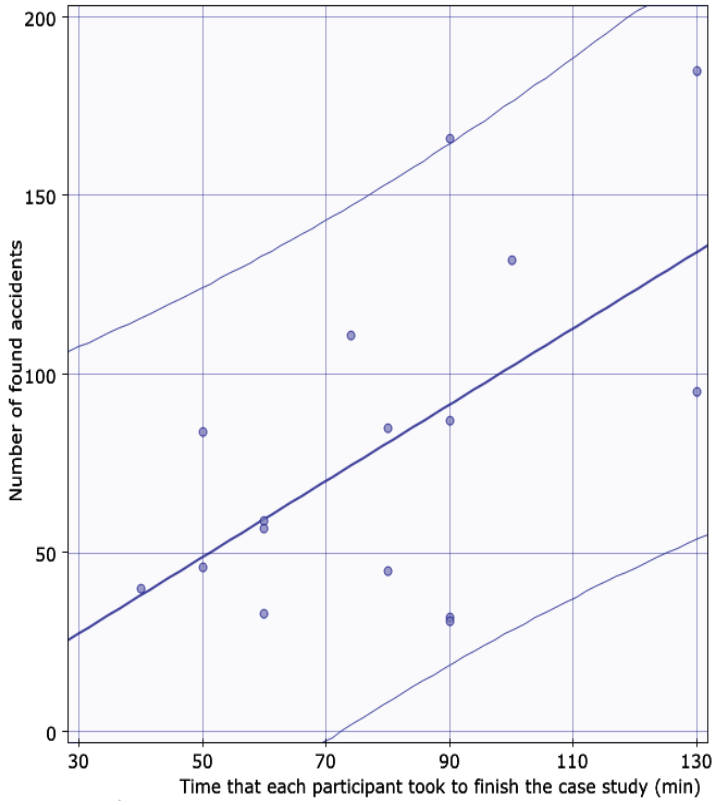

Fig-17: The time that each participant took to finish the case study vs. number of found accidents

6.1.3.3 Feedback from the participants:

Almost all participants agreed that the concept of AMDHH is easy to understand and the steps were easy to conduct. However, they mentioned some reservations to increase the effectiveness of AMDHH:

- AMDHH guidewords were helpful to enrich imagining deviations but some of their meanings have some ambiguity. Examining AMDHH at a variety of consumer products, their meanings or definitions may be much clear

- Steps from 1 to 3 are better to be done in-group not individually to reduce workload
- Forecasting deviations is limitless, of course, but stopping rules that he/she could stop forecasting if they cannot imagine more deviations is somehow vague. Some clear stop rules could be made to avoid dropping into forecasting of nonsense deviations, for example deviations that has criminal intention

6.1.4 The discussion of the results of case study

By using AMDHH, participants manage to discover 54 hidden hazards. Tasks set consists of different contents and procedures that should be followed, which could explain why around half of the hidden hazards were in method item. However, this was the case when AMDHH has been applied on the ladder in the experiment, therefore, the distribution of hidden hazards among five items could differ depending on the type of the targeted product.

From looking at the discovered 54 hidden hazards, it was noticed that highly repeated hidden hazards tend to be from the task contents of the targeted product; the ladder has potential energy from its height, which is rather clear. On the other hand, for low repeated hidden hazards, this could reflect that the deviation cause accidents through some specific process hard to forecast; low back pain when using ladder too long time is the example. It needs some ergonomic knowledge to forecast. Based on this, it might be good to check whether the person who would use AMDHH has some

pre-experience about general safety ergonomic knowledge to prevent missing hidden hazard. Moreover, for low repeated hidden hazards, without using the guidewords it could be difficult to discover them; this reflects the effectiveness of the guidewords for finding them.

6.2 EVALUATION FROM COMPANIES

6.2.1 The purpose of the evaluation from companies

The purpose of the evaluation from companies was to obtain an evaluation about AMDHH from people in charge of product safety based on their business experience.

6.2.2 The method of the evaluation from companies

A blank evaluation sheet includes set of questions and AMDHH manual were distributed to safety management staff of the quality assurance section and designers with product safety experience at companies, they were also given to specialists in product safety. The results of the experiment have not been submitted to them to avoid any kind of influence on their evaluation. They were asked to participate voluntarily in the evaluation and any other kind of financial interest or benefit does not exist among the authors. They have been asked to read the manual and the illustration examples written in it then they were required to imagine or actually conduct the AMDHH process by themselves. After that, they were asked to answer the evaluation sheet that includes a set of questions about the following:

1- Any previous record of having accidents from hidden hazards and the used method to handle them

2- Agreement or disagreement on the concept of AMDHH

3- Positive and negative points on AMDHH

4- Types of products that AMDHH is thought to be effective

5- The ability of using AMDHH in the case of having little risk assessment experience

6- Other purposes that AMDHH is capable of fulfilling

6.2.3 The results of evaluation from companies

26 evaluation sheets have been received; 14 from designers of consumer products at large-scale companies, 5 from safety staff at large-scale companies, 3 from designers at small-scale companies, 1 from safety staff at small-scale companies, and 3 from insurance companies and safety institutes. The answers are as follows:

1. Previous record of having accidents from hidden hazards: 23 companies said yes and 21 companies from them did not have a specified method to discover hidden hazards.

2. Agreement or disagreement on the concept of AMDHH: Fig-18 shows the responses; 15 companies agreed completely; the main reason was that AMDHH is close to user point of view not the designer. It could help to imagine how the user will use the targeted product and as a result it could help in delivering appropriate usage of the targeted product to the user to avoid accidents occurrence.

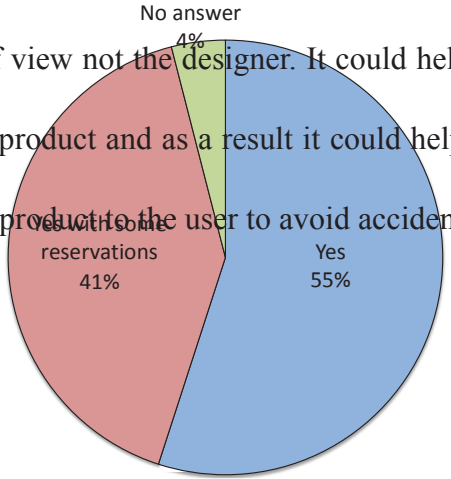

Fig-18: Agreement on the concept of AMDHH

10 answered yes with some reservations; they pointed that providing information about targeted product and the existent of specialists who have a good background about the targeted product are important things for proceeding AMDHH.

3. Positive and negative points on AMDHH: for the positive points, they could be summarized:

- The five items could help in finding where the accidents are likely to occur
- Easy to adopt method because of the five items model, guidewords, etc.
- A novelty in introducing the idea of the second user; it is rare in risk assessment methods

As for the negative points or disadvantages of AMDHH, there were no specific comments related to negative points or disadvantages but there were some reservation comments and they are as follows:

- Since there are a variety of consumer products, design and features guidewords

should have the capability to cover this variety. Guidewords could be added through applying AMDHH to various products

- The explanation of some terms like hidden hazards had better be written in more detail to avoid ambiguity

4. Types of products that AMDHH is effective on them to conduct risk assessment: good for products that have a variety of users and circumstances like the place of use.
   - Home equipment especially small children are involved in as accidents causation
   - New products because the absence of accidents history in the market.
   - Instruments with task flow that should be followed precisely like medical equipment

5. Ability of using AMDHH in the case of having little risk assessment experience: it is an easy to understand and easy to apply method, for that AMDHH has the capability to help in the case of having little risk assessment experience.

6. Other purposes that AMDHH is capable of fulfilling: examples of the answers are:
   - Product planning and concept design
   - Design review and designing the product manual
   - Educational tool for risk assessment for designers

6.2.4 The discussion of the results of evaluation from companies

Almost all companies agreed that hidden hazards caused accidents are problematic. The methods that are been used by them were not designed to handle hidden hazards problem. The number of agreement on AMDHH concept is an indicator that it could have a good chance of handling the problem of hidden hazards to promote safety aspects at consumer products.

Including the five items, especially the secondary user that is rarely treated in risk assessment methods, and easiness in conducting were good points in AMDHH process. It is allowable to add more guidewords and to refine the unclearness of some terms in AMDHH process. AMDHH have the basic capability to help in the case of having little risk assessment experience. Based on evaluation sheets results, AMDHH could be helpful to fulfill other purposes like educational tool risk assessment.

6.3 GENERAL DISCUSSION OF AMDHH BASED ON THE RESULTS OF CASE STUDY AND EVALUATION FROM COMPANIES

The term hidden hazard itself could be confusing but companies were facing problems related to hidden hazards as was seen from the responses, the results of AMDHH for both case study and the companies' evaluation gave a good indicator that

AMDHH could be a good solution to handle the problem of hidden hazards accidents beside fulfilling other purposes like risk assessment education. Since AMDHH targets the hidden hazards, it could be used with AMWAR or with any other risk assessment process or method since the issue of hidden hazards is not addressed by a specific and systematic method like AMDHH. As suggestions to improve AMDHH, it was suggested to increase the number of guidewords to cover more deviations, clarifying the meaning of hidden hazard more in the textbook of AMDHH to eliminate any possibility of misunderstanding its meaning.

6.4 SUMMARY OF THIS CHAPTER

In this chapter, Chapter 6, the case study and companies' evaluation of AMWAR was presented in detail. For the case study the results and the discussion of the results were presented, the same was for companies' evaluation. At the end a general conclusion from both the case study and the evaluation were presented.

Chapter 7

Overall General Discussion, Future View, and Final Conclusion

This chapter talks about the general summary of the study, findings from this study and the suggested next actions in the future to promote safety at consumer products.

7.1 OVERALL GENERAL DISCUSSION OF THE ENTIRE STUDY

The purpose of this study was as follows:

- Help in discovering as many as possible of the different obvious and hidden hazards that stand behind accidents
- Help in Forecasting as many as possible accidents when using consumer products in a comprehensive way that covers most of the circumstances around the product targeted
- Help in reducing the workload when being used
- Does not required long training sessions or acquiring certain skills

To accomplish that purpose two risk assessment methods were designed and developed. The first method was AMWAR (Analysis Method of the Worst Accidents Reasons), it was designed to treats the problem of accidents from obvious hazards in a comprehensive way and to reduce the workload when conducting risk assessment by focusing only on the worst accidents that have high-risks and forecasting. The finalized shape of AMWAR was as follows:

1. Identify the obvious hazards in the targeted product, using the obvious hazards list

2. Identify the worst accidents that could result from the obvious hazards contained in the product targeted by imagining them
3. Identify the direct reasons of the worst accidents by using a type of analysis called Sabotage analysis
4. Find the scenarios that cause the direct reasons by trying to imagine them with the use of designed sets of guidewords for each one of the five main elements in the context of use
5. Check the countermeasures of the targeted product against the found scenarios

Case study and companies' evaluation were conducted to see for what degree AMWAR met the requirements of forecasting worst accidents from obvious hazards, and being an easy to use method that does not required high level of skills or long training session. The results showed that, AMWAR met the requirements for far good level which indicates that it could be a good supporting tool for the manufacturers of consumer products when dealing with obvious hazards cases.

The second method is AMDHH (Analysis Method to Discover Hidden Hazards), it was designed to treats the problem of accidents from hidden hazards a comprehensive way. The finalized shape of AMDHH was as follows:

1. Writing the appropriate usage for the product targeted conducting tasks set
2. Forecasting deviations from the appropriate usage by using the designed guidewords for each one of the five main elements in the context of use

3. Finding the accidents in the deviations forecasted, hidden hazards are deviations that led to accidents
4. Accidents risk evaluation with the use of risk matrix
5. Checking the countermeasures state

Case study and companies' evaluation were conducted to see for what degree AMDHH met the requirements of forecasting accidents from hidden hazards in a comprehensive, and being an easy to use method that does not required high level of skills or long training session. The results showed that, AMDHH met the requirements for far good level which indicates that it could be a good supporting tool for the manufacturers of consumer products when dealing with hidden hazards cases.

AMWAR and AMDHH also could be used as supplementary methods with ISO/IEC guide51 to reduce the workload when handling obvious hazards and to discover hidden hazards, beside of course making the risk assessment process more comprehensive with the help of the five items and their guidewords sets. With other risk assessment methods like Be-safe method they could be used at the scenario part to cover as much as possible of the scenarios, with FMEA method they could be used to help covering the external influences or surrounding circumstances which is considered as one of FMEA disadvantages. Table-23 shows the fields that both AMWAR and AMDHH target beside the other possible fields that were found from the results of case study and evaluation.

Table-23: The targeted and possible fields for both AMWAR and AMDHH

The proposed risk assessment methods	The targeted filed	Possible other fields
AMWAR	The field of tangible consumer products category that are not highly S.W oriented products	risk assessment education, insurance business
AMDHH		risk assessment education, equipment like medical equipment that require following task flow precisely

7.2 ACADEMIC FINDINGS AND A VIEW TO THE FUTURE

From the outputs of the two case studies, it seems that there is a need for educational tool that could help in learning and building skills of the appropriate way to conduct risk assessment. Moreover, different fields require that the people who are experts in that field to do the work of risk assessment, if those experts in their fields have good educational tools that could help them gain more knowledge about risk assessment they could build their own risk assessment methods or tools and having their own know-how about risks and accidents related to their products. Beside the educational need, some product manufacturers seem to look for a way to walk-through the entire process of manufacturing the product and at the same time conducting risk assessment. It seems that they are looking for the possible accidents that could occur and taking the countermeasures at that time instead of waiting until the final product get made and released to the market especially in the case of new products that do not have any

history in the market, this could prevent or at least reduce the possibility of recall cases.

As next actions, the following could be done to improve the two methods:

- Applying AMWAR and AMDHH on different consumer products
- Trying to use AMWAR and AMDHH as educational tool for risk assessment
- Trying to apply AMWAR and AMDHH on different stages of manufacturing process

At the same time there are other topics worth to be addressed to promote safety aspects at consumer products and they are as follows:

- The possibility of the existence of other types of hazards except the obvious and hidden hazards
- Looking for the problem of workload when having hidden hazard.
- Studying the distribution of accidents between the context of use five items, it could help in finding the probability of accident occurrence from one of the items when using a certain category of consumer products which may help in the future predicting those probabilities by using data instead of just subjective opinions

7.3 FINAL CONCLUSION

The occurrence of accidents while using consumer products is a series issue, with the rapid increase of new consumer products that being released to the market, there is

always a possibility of accident. No Hazard No Accident, hazard is the way or the key to forecast an accident as was seen in both AMWAR and AMDHH, identifying the hazard is critical for any risk assessment process or method. This study was a try to draw the attention to the possibility of creating and developing new processes to help in minimizing accidents occurrence by forecasting them in advance. The hope is that AMWAR and AMDHH methods would help to draw the attention to accidents from both obvious and hidden hazards. Also encouraging conducting more studies to promote safety aspects at consumer products to prevent accidents from occurring as much as possible.

7.4 SUMMARY OF THIS CHAPTER

This chapter was a general summary for the entire materials in this study. Starting from the purpose of this study, case studies, and companies' evaluation. Then the academic findings and the future planned actions were presented. Finally, a message that we tried to deliver through this study.

ACKNOWLEDGEMENT

I would like to express my sincere thanks to all people who helped and participated in this study especially on the first place professor Akinori Komatsubara who has guided me as a supervisor for this study. Also, would like to give special thanks to professor Yasushi Nagata, professor Tomoji Kishi and professor Masayuki Goto, who gave me the best comments as reviewers for this thesis. Also of course cannot forget to mention professor Manabu Sawaguchi who kindly gave me a lot of valuable information regarding Sabotage Analysis. Without their guidance and support this study could not have been accomplished.

References

1- Rider, G., Milkovich, S., Stool, D., Wiseman, T., Doran, C., and Chen, X.: Quantitative Risk Analysis, Journal of Injury Control and Safety Prevention 7 (2) :115-33, 2000

2- Gagg, C.: Domestic product failures -case studies, Engineering failure analysis 12 (5): pp. 784-807, 2005

3- National Institute of Technology and Evaluation (NITE): Seihin Jiko kara Mi wo Mamoru tameni, Mi・Mamori Hando Bukku (The Hand Book of Protecting Oneself from Product Accidents), NITE, 2013

4- Bamber, L.: Principles of Accident Prevention, In Safety at Work. ed, J. Ridley, pp. 131-143, Butterworths, London, 1986

5- ISO/IEC: ISO/IEC guide51: Safety aspects — Guidelines for their inclusion in standards, 3rd version, ISO/IEC, 2014

6- ISO: ISO 12100: Safety of machinery – General principles for design – Risk assessment and risk reduction, ISO, 2010

7- ISO: ISO10377: Consumer product safety – Guidelines for suppliers, ISO, 2013

8- IEC: IEC 62366-1: Medical devices – Part 1: Application of usability engineering to medical devices, IEC, 2015

9- National Institute of Technology and Evaluation (NITE): Shouhi Seikatsuyou Seihin no Goshiyou Jiko Boushi Hando Bukku, Jigyousha no Higoro kara no

Torikumi no Tameni (The Consumer Products Hand Book of Misuse Accidents Prevention, For Companies' Daily Efforts), NITE, 2005

10- U.S. Department of Labor, Occupational Safety and Health Administration (OSHA): Job Hazard Analysis, OSHA, 2002

11- Matsumoto, K.: R-Map to Risukuasesumento (R-Map and Risk Assessment), Nikka Giren, 2016 / 10 / 11

12- Simpson, G. C.: Promoting Safety Improvements via Potential Human Error Audits, In Proceeding of the 25th Conference of Safety in Mines Research Institutes, Pretoria South Africa, SA Chamber of Mines, 1994

13- Rachel, B. and Sarah, M.: Applying the BeSafe Method to Product Safety Evaluation, Applied Ergonomics Human Factors in Technology and Society, Vol. 29, No.1, pp. 5-13 (1998)

14- Ergonomic and Safety Management Unit, The BeSafe Training Support Manual, International Mining Consultants Ltd, Burton-on-Trent, 1995

15- Simpson, G. C, Talbot, C. F, Rushworth, A. M.: BeSafe from Knobs and Dials to Safety Management, Personal Communication, 1997

16- MIL-STD-1629A: Procedures for Performing a Failure Mode, Effects and Criticality Analysis, 1980

17- Clifton, A. Ericson. II.: Hazard Analysis Techniques for System Safety, Wiley-Interscience 1st edition, 2005

18- Tanaka, K.: FMEA: An Effective Method for Preventing Troubles, J. Natl. Inst. Public Health, 51 (3), 2002

19- Iida, S., Kanauchi, S., Yanagawa, T.: FMEA no Kisochishiki to Katsuyoujirei―Enshuu Mondaitsuki (Basic Knowledge and Practical Case Studies) (Shiri-zu Iryou Anzen Kakuho no Kangaekata to Shuhou) (Series of Maintaining Medical Safety Way of Thinking and Methods), Japanese Standards Association, 2014 / 7

20- Lynne, H., Treasure Chest of Six Sigma Growth Methods - Tools - Best Practices, Prentice Hall, 2008

21- Hanamura, W., Hirose, Y.: Seisan Kakushin ni Taiou Shita Koutei no FMEA & FTA niyoru Hinshitsu Mondai no Mizen Boushi Katsudou (Preventing Quality Problems via the Use of FMEA & FTA for Innovative Industry), Institute of Systems - Control - Information Engineering, Vol. 52, No.4, pp. 148-152, 2008

22- Nakanishi, T., Hisazumi, K., Fukuda, A.: A Software FMEA Method and Its Use in Software Product Line, Institute of Electronics - Information and Communication Engineers (IEICE), 111(481), pp. 19-24, 2012 /3/6

23- Masuda, A., Iwase, T., Suzuki, K.: Development of Three Element FMEA Considering the Interaction between Human, Environment and Equipment for Reliability and Safety Analysis, Journal of the Japanese Society for Quality Control, Vol. 29, No. 1, pp. 122-135, 1999

24- Kanis, H.: Usage Centered Research for Everyday Product Design, Applied Ergonomics 29 (1): pp. 75-82, 1998

25- Hecht, M.: The Role of Safety Analysis in Reducing Products Liability Exposure in “SMART” Consumer Products Containing Software and Firmware, Proceedings of the Annual Reliability and Maintainability Symposium, 153-58, 2003

26- John, R.: Safety at Work, 3rd Edition, Butterworth-Heinemann ltd, 1990

27- Sanders, M., McCormick, E.: Human Factors in Engineering and Design, 7th ed, New York: McGraw-Hill, 1993

28- Clark, D.R., Lehto, M.R.: Information Design: Warning Signs and Labels. International Encyclopedia of Ergonomics and Human Factors, ed. W. Karwowski, 1152-55. London: CRC Press, 2006

29- Ministry of Economic, Trade and Industry in Japan (METI): Consumer Products Definition, METI, 2017

30- ISO: ISO 45001:Occupational health and safety management systems - Requirements with guidance for use, ISO, 2018

31- IPA/SEC: Embedded System Development Quality Reference (ESQR), IPA/SEC, 2010

32- IEC: IEC 61508 Functional safety essential to overall safety, IEC, 2015

33- Bonner, J.V.H.: Human Factors Design Tools for Consumer-Product Interfaces, International Encyclopedia of Ergonomics and Human Factors, ed. W.Karwowski, 1839-42. Florence, KY: Taylor & Francis, 2001

34- Guy, A. B.: The Handbook of Human-Machine Interaction - A Human Centered Design Approach, Ashgate Publishing Limited, 2011

35- Van Veen, M.P., Van Engelen, J.G.M., and Van Raaij, M.T.M.: Crossing the River Stone by Stone: approaches for Residential Risk Assessment for Consumers, Annals of Occupational Hygiene 45:S107-18, 2001

36- Consumer Product Safety Association (CPSA) : Kodomo Seihin no Anzensei ni Kansuru Chousa Kenkyuu (A Research Investigation about the Safety of Children’s Toys), Shouhi Seikatsuyou Seihin no Seizou – Kyoukyuu ni Kakawaru Risuku Kanri ni Kansuru Chousa Kenkyuu Houkokusho (The Report of Research

Investigation about the Manufacturing of Consumer Products and the Related Supply Risk Management), 2002

37- Waldemar Karwowski. Marcelo M. Soares. Neville A. Stanton: Human Factors and Ergonomics in Consumer Product Design – Uses and Applications, CRC Press, 2011

38- Mimura, T.: Product Safety-Consideration from a Consumer's Point of View, Journal of Reliability Association of Japan, Vol. 30, No. 6, 2008

39- Rider, G., Van Aken, D., Van De Sman, C., Mason, J., and Chen, X.: Framework Model of Product Risk Assessment, International Journal of Injuries Control and Safety Promotion 16 (2), pp.73-80, 2009

40- Sawaguchi, M.: Gyakuten-Hassou niyoru Souzouteki Risuku-Asesumento (Sabotage Analysis), Doyu-kan, 2007

41- Katoh, S.: Sabotaaju–Anarishisu niyoru Houshasen Kanri no Risuku Taisaku (Risks' Countermeasures at the Management of Radioisotopes by Sabotage Analysis), Isotope news (661), pp.14-16, (2009)

42- Sawaguchi, M., Nakahara, I.: Verification of Risk Countermeasures Regarding Expressway Traffic Control System Based on Creative Risk Management Approach, Proceedings of PICMET '14: Infrastructure and Service Integration, pp. 3430-3440, 2014

43- Sawaguchi, M.: Research on the Efficacy of Creative Risk Management Approach based on Reverse Thinking, Procedia Engineering 131, pp. 577 – 589, 2015

44- Bonkobara, K., Altiyare, H., and Komatsubara, A.: A study on Risk Assessment Process based on Sabotage Analysis for the Safety of Consumer Products, Journal of Human Life Engineering, Vol. 13, pp.5 9-64, (2012)

45- Chamorro-Koc, M., Popovic, V., and Emmison, M.: Human Experience and Product Usability: Principles to Assist the Design of User-Product Interactions, Applied ergonomics, Vol 4, issue 4, pp. 648-656, 2009

46- Komatsubara, A.: Proposing a Methodology to Specify Usage Conditions for Product Safety, Journal of Human Life Engineering, Vol. 10, pp. 36-40, (2009)

47- JoAnn, T. and Janice, C.: User and Task Analysis for Interface Design, John Wily & Sons, Inc., NY, pp. 28-29, (1998)

48- Ergonomics of Human-System Interaction part 210: Human-Centered Design for Interactive Systems, Reference number ISO 9241-210:2010(E)

49- Trevor, A. Kletz.: Hazop & Hazan, Warwickshire, CRC Press, 1999

50- Yoshinobu, N., Toru, E., Ryoji, F., and Hiroyuki, M.: The Seven New QC Tools, 3A Corporation, (2007)

51- The Committee for Developing QC Tools.: Management for Quality Improvement – the New QC Tools, Productivity Press, 1988

52- Yamaji, T.: PDPChou niyoru Kainan Bunseki – Ondonoseto wo Taishou toshite – (Marine disaster analysis by PDPC method. For Ondonoseto.), The Operation Research Society of Japan, Vol.41, No.11, pp. 646-651, (1996)

Appendix A

AMWAR Manual

1 AMWAR コンセプト：

AMWAR では、「事故をどうやって起こすか」「誤用をどうやって起こすか」という点からリスクアセスメントを行うものです。リスクアセスメントの経験を持っていないデザイナーや企業がリスクアセスメントをできるようになるために作られた援助手法です。長い分析時間と高いワークロードを避けることを本手法の目標としています。

2 AMWAR モデル：

AMWAR モデルでは、製品使用に影響を及ぼす項目には五つのものあり、この五つの項目と、製品に内包されるハザード（危害要素）の組み合わせから事故が起こってしまうという考え方をしています。

製品使用に影響を及ぼす五つの項目には、以下のものがあります：

- ユーザー：ユーザーは三つの種類に分かれます。
  - プライマリユーザー（primary user）：製品を使用しているユーザー
  - セカンダリーユーザー（secondary user）：プライマリユーザーが製品を使用する際に影響を受ける人
  - シートメイト(Seatmate)：製品が使用される際に近くにいる人

  【例】

  電気ドリルを使う際に、ドリルを持って使っているユーザーはプライマリユーザーであり、隣でドリルのネジを持ってプライマリユーザーを援助する人はセカンダリーユーザーである．また，作業には関係がないが、たまたまその作業現場に居合わせた人は、シートメイトである。
- 環境： 製品が使用されている場所

- 使用時間： 製品が使用されている時間
- 使用方法： 製品の取り扱い方
- 周囲にある別の製品：本製品の周囲にあって、その製品や製品使用に影響を与える他の製品

上に書かれている五つの項目を図 2-1 に示します。これらの項目は、事故の起因要素と考えられます。ある製品の使用に関る事故を予見するということは、製品に含まれるハザードと、これらの事故の起因要素を見つけ出すと言い換えることが出来ます。事故の起因要素を見つけ出すためには、自由発想を行います。事故は、ハザードと、事故の起因要素との掛け合わせ。事故の起因要素には、大きく５つの項目があり、図 2-1 に示されいます。

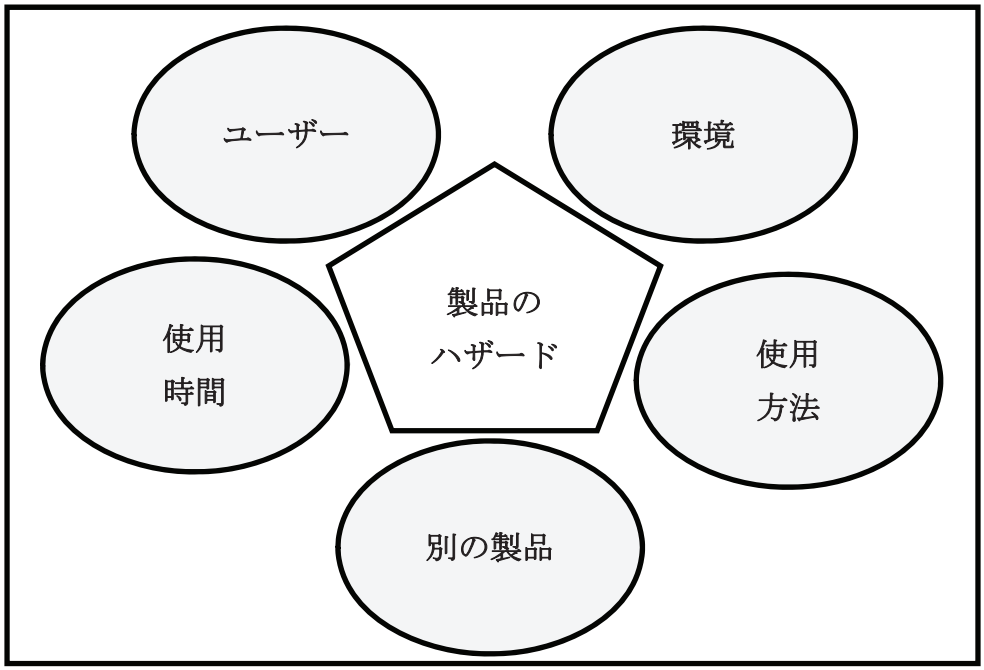

図 2-1：AMWAR モデル

3 AMWAR プロセス：

AMWAR は次の５つのステップで行われます：

1. 対象としている製品に含まれているハザードをチェックし、見つけ出す：

評価対象としている製品に含まれる、電気ハザード、化学ハザード、機械ハザード等といったハザードを見つけ出します。AMWAR では、ハザードがなければ事故は起こらないと仮定します。これを No Hazard, No Accident の原則といいます。したがって、対象製品にハザードが含まれているかどうか、まずチェックします。ハザードがわかれば、そのハザードがもたらす最悪事故がわかるからです。ハザードの確認を行いやすくするために、表 3-1 に示すハザードリストを用います。

表 3-1：ハザードリスト （OSHA に基づく）

ハザード	ハザード定義
化学(毒性)	皮膚の接触や呼吸（吸引）により体内に取り込まれ，病気または死を引き起こす毒性のある化学物質
化学(可燃物)	熱により、引火したり、燃焼する化学物質。
化学（腐食性）	皮膚についたり、あるいは金属や他の材料と接触すると、それらにダメージを与える化学製品。腐食性のあるものの

	例として，酸やアルカリがあげられます。
爆発（化学反応）	爆発性のあるガス、有機溶剤など。
爆発（加圧）	例えば、ボイラーまたは圧縮したガスシリンダーのようなもので、その圧力によって爆発を起こします.
電気(感電／ショート）	誤って、または、不注意に、直接的に、あるいは間接的に充電部に接触する。直接的とは身体の一部が充電部に接触することで、間接的とは、例えば、金属はしごが送電線と接触するといったことです。
電気(火災）	通電部が発熱することや、アーク（火花）が飛ぶこと。さらに可燃物の着火につながる電力の過剰な使用や、電気部品が破損しているのに使用することも、電気火災につながります。
電気（静電気）	ウール、ナイロン、他の合成繊維を動かしたりこすったりすることで、高圧の静電気が生じます。さらには流れる液体さえ、静電気を発生させるものです。静電気の電撃により身体がダメージを受けたり、可燃物の着火や、他の電子機器の故障をもたらします。
電気（電源喪失）	電力喪失の結果として、安全上の重要な器材故障につながることがあります。

人間工学（負担）	過負荷（重量物の保持や無理な姿勢）、または反復的な運動のため、身体がダメージを受けることがあります。
人間工学（ヒューマンエラーの誘発）	エラーを誘発する機器のデザイン、手順。たとえば何かをオフにするためにスイッチを「上げる」といったことは、エラーを誘発します（普通、スイッチを切る操作はスイッチを「下に」切るものだから）。
人間工学（不注意・偶発）	人によって引き起こされた行動の結果としての怪我。（ネジ回しがすべって、身体にぶつかることなどが事例です。）
人間工学（落下や滑落、転倒）	手に持っているものをすべり落としたり、自分自身が転落したり、転倒すること。「滑りやすい」ことが問題となります。
火炎／熱	皮膚または他の身体部位へのダメージや火傷を引き起こすことがありえる温度。火災を起こす温度。火災は、熱源があり、燃えるものと酸素があるときに生じます。
機械（振動、疲労）	身体の末梢神経に損害を引き起こしうる振動。材料の重大な疲労をもたらす振動。例えば吊りひもとロープの摩擦、ホースやベルトの摩滅など。
機械（故障）	装置が設計された性能を発揮しないことや、動かなくなってしまうこと。

機械（形状、によ動きる負傷や、他の機器を壊すこと）	人間の皮膚、筋肉または体の一部が切断，裂傷、打撲を受けること。鋭利な部分への突き刺し、閉塞する空隙への挟まれ、回転体への巻き込まれ、動作部分の衝突などにより生じます。これらは他の機器の破損にもつながります。
騒音	騒音レベル（85dBA で 8 時間の暴露）によって、聴力損失を受けることがあるといわれます。また、騒音下では、安全上重要な情報を聴取できなくなります。
放射線	身体組織の損傷の原因となるアルファ線、ベータ線、ガンマ線、中性子線や、X線。
放射線（非電離）	身体組織を傷つける紫外線、可視光線、赤外線，熱線や、光化学物質。
加速物への衝突	加速物に衝突し，死傷を起こすもの。 （落下物や発射体などが事例として上げられます）
過度の温度（高温/低温）	高温は熱傷にならないまでも、熱によるストレスや疲労をもたらし、低温は凍傷や低体温症のようなストレスをもたらします

2. 対象としている製品を用いる際に起こりえる最悪事故を予見する：

ハザードを見つけ出した後、そのハザードによりもたらされる最悪事故を予見します。最悪事故とは、死亡やひどい怪我等といった高いリスクの事故のことです。

3. 起こりえる最悪事故の原因となる使用を明確にする：

最悪事故を発生させる原因となる使用を明確にします。このとき、５つの事故の起因要素を考慮します。例えば、対象としている製品が電気コードのとき、ハザードは電気ハザードであり、最悪事故を火災とすれば、電気コードを過負荷使用するのが、最悪事故の原因となる使用となります。

4. 原因を起こすシナリオを明確にする：

原因を起こすためのシナリオを明らかにします。例えば、電気コードの過負荷であれば、その電気コードにつながった一つのコンセントにたくさんの電気機器をつなぐ、といったことがシナリオとなります。出来るだけたくさんのシナリオを見出すために、ガイドワードを用います。事故は二章に述べた五つの項目が影響し、起こります。そこで五つのガイドワード群が AMWAR では準備されています。以下の表にその五つガイドワード群と、各ガイドワードの定義を示します。

表 3-2：使用時間に関するガイドワード

ガイドワード	定義
使用時間の長さ	対象としている製品の一回あたりの使用時間
使用回数	対象としている製品の使用回数。何回製品を使用するのか

表 3-3：ユーザーに関するガイドワード

ガイドワード	定義
年齢	対象としている製品のユーザーの年齢
態度	対象としている製品を使用する際のユーザーの態度と行動。例：落ち着いて製品を使用していない
知識	対象としている製品の使用のために必要なスキルと知識
精神状態	対象としている製品を使用する際のユーザーの精神状態。例：覚醒状態
身体状態	対象としている製品を使用する際のユーザーの身体的な状態。例：身体障害や、体力

表 3-4：製品の使用環境に関するガイドワード

ガイドワード	定義
空間	対象としている製品を使用する場所
パワーソース	対象としている製品を使用するために必要な電源などのエネルギー源
照明	使用する場所の照明など、明るさ
雰囲気	現場に影響を与える雰囲気。例：人間関係や監督との関係

表 3-5：周囲にある製品に関するガイドワード

ガイドワード	定義
動かされる	他の製品によって、その製品が起動してしまう
ダメージ	周囲にある製品からダメージを受ける
影響	周囲にある製品から影響を受ける。例：他の製品からの電気的干渉

表 3-6：製品の使用方法に関するガイドワード

ガイドワード	定義
早すぎる	対象としている製品を使用するためのタスクを、必要より早く行う。例：熱を発する製品を消した後で、すぐに触ったり、運んだりする
遅すぎる	対象としている製品を使用するためのタスクを必要より遅く行う。「早すぎる」というガイドワードと正反対の意味である。
過剰	対象としている製品を使用するためのタスクを、必要より過剰に行う。例：過剰な力を使って行う、過剰な回数触れてしまう

少ない	対象としている製品を使用するためのタスクを、必要より過少に行う。例：過少な力で使う、過少な回数でしか触れない
乱れる	タスクフローの順序が乱れる、　使用順序を間違えるなど
飛ばす	タスクを飛ばす
保存	製品の保存の仕方
乱暴	乱暴に製品を取り扱う

5.　原因に対する対策の状況の確認：

最悪事故を回避するための対策が、その製品で取られているかを確認します。電気コードがつながった一つのコンセントに多数の電気機器をつなぐ例であれば、電気コードの容量は十分大きいか、過負荷遮断スイッチがついているか、警告表示が書かれているか、などを確認します。もし、適切な対策が取られていなければ、その製品では、そこから事故が起こる可能性があります。

次の部分は AMWAR を用いた事例研究について、説明します。

4 AMWAR 試用例

対象：リモコン付き電気ストーブ。図 **4-1** に対象としている製品を示します。

あるチームが AMWAR を実施しました。その結果は以下のとおりでした。

図 4-1：対象とする製品

4.1 対象としている製品に含まれているハザードをチェックし、見つけ出す:

ハザードリストを参考に検討した結果、製品に含まれているハザードは以下の 5 つであると特定されました。

- 化学(毒性)：電気ストーブには塗料などに様々な化学物資が使われており、かつ製品は熱を発するため、化学物質の蒸発による化学ハザードがある。
- 電気ハザード(感電／ショート)：製品は電気で動くため、感電／ショートの電気 ハザードがある。
- 電気ハザード(火)：製品は電気で動くため、火気の電気ハザードがある。
- 機械ハザード：製品に鋭い角があるため、機械ハザードがある。
- 火災／熱：製品は熱を発するため、火災／熱ハザードがある。

4.2 対象としている製品を用いる際に起こりえる最悪事故を予見する:

明らかとなったハザードに対して、起こりえる最悪事故を整理し、結果を表 4-1 に示します。

表 4-1：製品に含まれているハザードと最悪誤用事故

含まれているハザード	最悪誤用事故
化学ハザード(毒性)	呼吸器系の病気
電気ハザード(感電／ショート)	死亡または、火傷の怪我
電気ハザード(火)	死亡または、火傷の怪我
機械ハザード	鋭い角で怪我する
火災／熱	死亡または、火傷の怪我

4.3 起こりえる最悪事故の原因となる使用を明確にする:

どうやって事故を起こすか、その原因を自由発想で検討しました。その結果を表 4-2 に示します。

表 4-2：最悪誤用事故の原因

含まれているハザード	最悪誤用事故	原因となる使用 : 事故はどうやって起こすか
化学ハザード(毒性)	呼吸器系の病気	毒性のガスの吸引
電気ハザード(感電／ショート)	死亡または、火傷の怪我	電源を直接触る
電気ハザード(火)	死亡または、火傷の怪我	電源に過負荷
		電気ストーブのサーモスタットの故障
機械ハザード	鋭い角で怪我する	鋭いエッジに触る
火災／熱	死亡または、火傷の怪我	熱源に触る
		可燃物と電気ストーブの接続

4.4 原因となる使用を起こすシナリオを明確にする：

次のステップでは原因を起こすシナリオを明確にします。製品に含まれるハザードと五つの項目関係から、原因を起こすシナリオを見つけ出します。五つの項目とのインターアクションエリアとは、以下のとおりです：

- 製品に含まれるハザードとユーザー（P-U）
- 製品に含まれるハザードと環境（P-E）
- 製品に含まれるハザードと使用時間（P-T）
- 製品に含まれるハザードと使用方法（P-M）
- 製品に含まれるハザードと周囲にある製品（P-RP）

表 4-3 に製品と環境のインターアクションエリアの結果を例として、示してあります。

4.5 原因を起こすシナリオに対する対策状況の確認：

最後のステップは対策の確認です。三章に述べたように、ここでの対策とは原因を起こすシナリオに対してとられているものを指します。試用例は原因となる使用を起こすシナリオを明確にするというステップまで行われました。次の表 4-3 では例として、製品と環境のインターアクションエリアの結果が示されています。

表 4-3 ： 製品と環境のインターアクションエリアの結果

含まれているハザード	最悪誤用事故	原因、どうやって起こすか	以下に書いてあるガイドワードに従って、原因を引き起こすシナリオを見つけ出す			
			空間	パワーソース	照明	雰囲気
化学(毒性)	呼吸器系の病気	毒性物質の吸引	高い熱源の近くに電気ストーブを置く			
			狭い密閉空間で高い熱源の近くに電気ストーブを置く。狭い場所なので、ガスが充満する			
電気ハザード(感電/ショート)	死亡または、火傷の怪我	電源に直接触る	暗い場所で電気ストーブを使う際、コードをつなぐときに手がコンセントに接触する			
電気ハザード(火)	死亡または、火傷の怪我	電源に過負荷	たくさんのコードを、容量オーバーの状態でコンセントに接続する			
			細い延長コードを使う			
		電気ストーブに倒れる場合の安全スイッチの故障				
機械ハザード	鋭い角で怪我する	鋭い角に触る	暗い場所に電気ストーブを置きとぶつかる			
			狭すぎる場所に電気ストーブを置き、とぶつかる			
火災／熱	死亡または、火傷の怪我	熱源に触る	暗い場所に電気ストーブを置き、ぶつかる			
			狭すぎる場所で電気ストーブを置き、とぶつかる			
			人々が行ったり来たりする場所に電気ストーブを置く			
		可燃物と電気ストーブの接触	狭すぎる場所で電気ストーブと可燃物を一緒に置く			
			電気ストーブを照明として使い、新聞や雑誌を読むために、電気ストーブに近づきすぎる			

Appendix B

AMDHH Manual

1 AMDHH コンセプト

消費生活用製品に含まれているハザードの中には，ハザードリストを用いると発見できるものもあります。例えば、電気ハザードや機械ハザードです。こうしたハザードは、その製品に明示的に含まれているハザードいう意味で、明示的ハザード（Obvious Hazards）といいます。一方、明示的ハザードが存在しない製品であっても，事故が生じることがあります。例えば、滑り台では，それ自体には明示的ハザードはなくとも、手すりを越えて子どもが地面に落下する事故が起きえます。明示的ハザードのチェックリストを用いたとしても、こうしたケースを予見することは困難です。こうしたタイプの事故は、製品のもつ隠れたハザード（Hidden Hazards）により引き起こされるもので、 AMDHH は、これを見出すための手法です。

隠れたハザードは，適切な用い方から逸脱（deviation）した用い方をすることで事故を引き起こされるものです。図 1-1 にこの考え方を示します。この逸脱を予見すれば、事故も予見でき、対策案も立案できると考えられます。

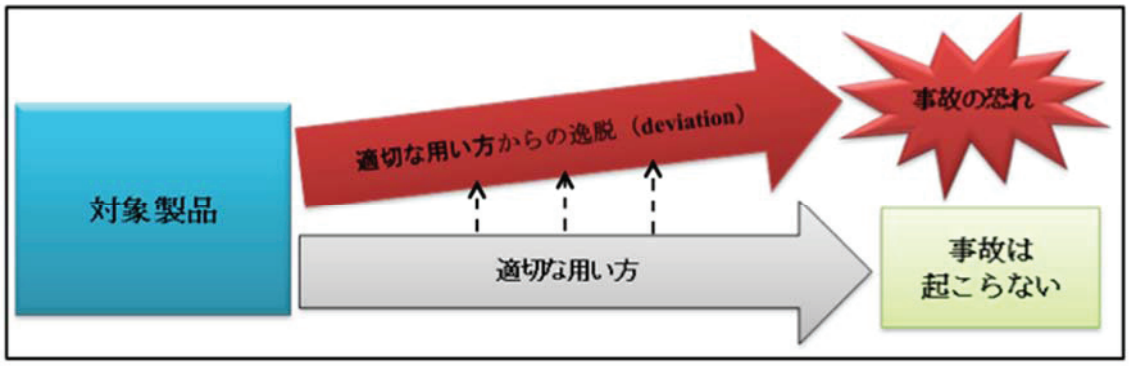

図 1-1 ： AMDHH コンセプト

2 五つの逸脱項目

事故につながる適切な用い方からの逸脱とは、図2－1に示す５つの項目において生じると考えられています。そこで、AMDHHでは、準備から廃棄まで、対象製品の使用段階において、これら5つの項目に関した逸脱を明確化していきます。

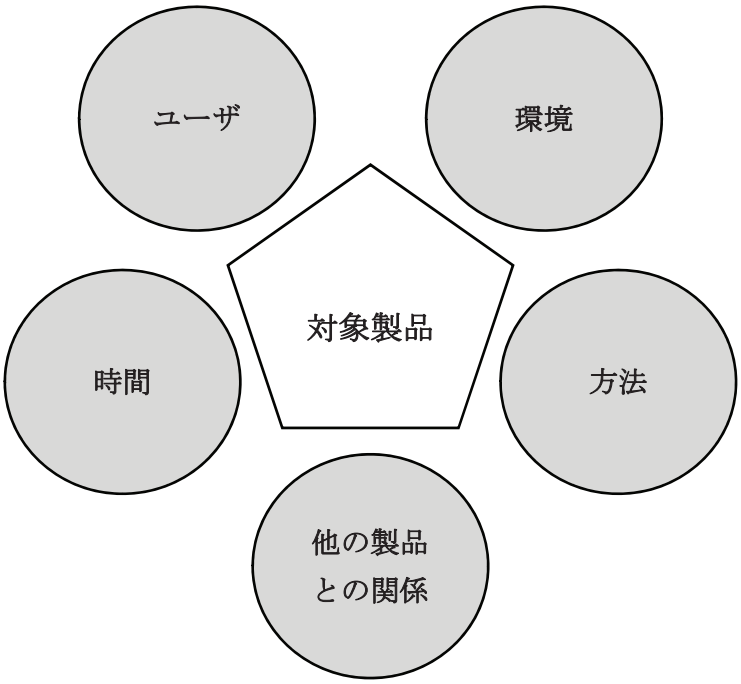

図 2-1　対象製品と五つの項目

なお、5 つの項目の説明は以下の通りです。自転車のチャイルドシート（図 2－2）を例に、事故との関係で説明します。

図 2-2 自動車チャイルドシート

1. ユーザ：その製品に関係する人。以下の 2 つの立場があり得ます。

   - 主使用者（Primary user）：その製品使用に主導的にかかわる人
   - 副次使用者（Secondary user）： 主使用者ではないが、その製品に当然、関係する人。主使用者の使用の影響を受ける人

【例】

・ **主使用者は**子供をシートに乗せたり、自転車をこいだりする成人（多くは保護者）。**副次使用者は**子供。

・ 望ましくない主使用者が使用すると事故が起こり得ます。例えば、チャイルドシートの使い方をよく知らない人が子供を乗せる、などといったことです（逸脱：主使用者）。

・ 副次利用者の逸脱もあり得ます。例えば、幼児用チャイルドシートに、新生児を着席させたり、中学生が着席するといったことです（逸脱：副次利用者）

なお、いつも副次利用者がいるというわけではなく、製品により、いたり、いなかったりします。

2. 環境：その製品が使用される環境です。その製品が使用される環境として、望ましくない環境条件（望ましい環境条件からの逸脱）のことです。

【例】

・ でこぼこ道の走行。副次利用者である子供に悪影響が及びます（逸脱：環境）

・ 雨ざらしであること。チャイルドシートの材質が劣化したり、シート座面が滑りやすくなり、副次利用者が滑ることもあります（逸脱：環境）

3. 方法：その製品の利用のされ方。

その製品の望ましい使用方法(使用手順)とは異なる方法での使用のことです。

【例】

・ 不確実な自転車への固定。子供のシートベルトを着用させないこと（逸脱：方法）

・ 乱暴な運転、チャイルドシートに子どもだけではなく、荷物も一緒に載せる（逸脱：方法）

・ 着席した幼児が自分でシートベルトを外して身を乗り出す（逸脱：方法）

4. 他の製品との関係：その製品の利用されるときに存在する製品その製品の利用や、安全に影響を与える他の製品（物）であり、推奨されない物が意図的に、あるいは意図せず使われることが、逸脱となります。

   ・ チャイルドシート自転車に固定するときに、推奨ではないボルトやビニールひもで固定する（逸脱：他の製品）。

   ・ チャイルドシードの上に不適切な厚さの座布団が敷かれる（逸脱：他の製品）

5. 時間：その製品が利用される時間帯や、利用期間（時間）の長さ。その製品を望ましくない時間帯に使用することや、望ましくない時間の長さ、望ましくない回数頻度で、使われることです。

【例】

   ・ 長時間の走行。振動から副次利用者の子供に悪影響を及ぼしたり、固定が緩んでシートが脱落することがあり得ます（逸脱：時間）

本手法では製品の使用段階において、これら５つの項目について逸脱を予見します。2.3 項では、実際の AMDHH プロセスの概要を紹介します。

3 AMDHHプロセス:

1 五つの項目の適切さの明確化：

準備から廃棄までの製品使用のどの段階を評価の対象段階とするかを決めます。

【製品の準備から廃棄までの段階例】

- 準備: 製品が用いられる前の準備段階
- 使用: 製品が実際に用いられる段階

- メンテナンス: 製品の保守や修理の段階
- 保存: 製品使用後の保存・保管の段階
- 廃棄: 製品の廃棄の段階

分析対象とする段階において、その製品の取扱説明書などに基づき、望まれる使用の仕方（タスク）を記述します。一般にタスクは、使用手順、操作手順として記述します。取扱説明書が付属していない製品であれば、常識的な「正しい使い方」を記述します。「適切なユーザ」「適切な環境」といった図 2-1 の項目は製品によっては、何が「適切」かが、はっきりとは言えない場合もあります。その場合には、空欄のままで構いません。

2 適切な五つの項目からの逸脱の予見：

明らかとした「適切なユーザ」「適切な環境」「適切な方法」「他の製品との適切な関係」「適切な時間」を基にして、逸脱をできるだけたくさん予見します。

- 逸脱は「適切な用い方」の単なる裏返しではなく、適切な使い方を基準として、事故に至る逸脱を幅広く予見します。
- 逸脱は無数に存在すると考えられますが、その評価対象製品の事故に明らかに関係しない逸脱を予見する必要はありません。
- 逸脱が明確に予見できない場合は、空欄のままで構いません
- 逸脱の予見においては、以下の表にあるガイドワードを利用するとよいでしょう：

  - ユーザ：タスクを実行する不適切なユーザを予見します。

表 2-1：ユーザのガイドワード

年齢（若すぎる、高齢すぎる）
身体特性（身体寸法、体重、筋力、身体的な障害の状態）
心身の状態（疲れている、焦っている、眠気が差している）

教育や経験（製品の使い方の理解、製品を使いこなせる必要なスキル又は体験）
態度や性格（製品を扱う態度、癖、慎重さ、集中力など）

- 環境：タスクが実行される不適切な使用環境を予見します。

表 2-3：環境のガイドワード

物理的な条件（製品の直接影響を与えるもの：振動、温度、湿度、など）
使用者の心身状態や使用能力に影響を与えるもの（騒音、雰囲気、触感、臭気、明るさ、など）
製品の使用の制限を与えるもの（地面や床面など接地面の状態、製品の移動や搬出入の障害になるもの）
自然環境（小動物の存在、海辺（潮風）、寒冷地・温暖地、天候、気象など）
社会的な条件（街頭／人ごみ、電気宗教や風習、風俗文化など）

- 方法：タスクが実行されるために、不適切な使用や取り扱いの方法を予見します。

表 2-4：方法のガイドワード

使用手順（順序違い、省略や手抜き、余計なことをする）
使用のタイミング（早すぎ、遅すぎ）
操作の仕方（乱暴、力が不足・過剰、不適切な工具の使用など）
使用のスピード（速すぎ、遅すぎ）
操作の姿勢（無理な姿勢、不適切な姿勢での操作など）
使用者の人数（二人で行うべきところを一人で行うなど）

- 周りの製品との関係：タスクが実行されるとき、評価対象の製品やタスク遂行に悪影響を与える製品を予見します。

表 2-5：周りの製品との適切な関係のガイドワード

対象製品に付けるもの（付属品、同時利用製品など）
ユーザが装着・着用しているもの（衣服、保護具など）

周辺に存在して対象製品に影響やダメージを与えるもの（電子機器に対して：電磁波ノイズを発するもの。樹脂製製品に対して：高温輻射熱を与えるもの　など）

- 時間：タスクが実行される不適切な時間帯、不適切な時間の長さ、不適切な使用回数を予見します。

表 2-6：時間のガイドワード

時間帯：夜間、深夜、早朝、日中など
時間の長さ：長すぎ、短すぎ
回数：多すぎ、少なすぎ、多すぎ

3 逸脱による事故の存在の確認：

逸脱があれば必ず事故に直結するわけではありません。よって、明確化した逸脱ごとに，ユーザ（適切なユーザ、不適切なユーザ双方）に傷害などの事故が生じるかを確認する必要があります。事故の生じる逸脱が隠れたハザードということです。確認をするとき、次の二つの点を配慮しながら、事故を見つけ出します。

1. 逸脱が起こったとしたら、どのような事故が引き起こされるかを考えます。
2. 事故に遭うのは誰かということを考えます。

4 ひどさと頻度の評価：

事故に繋がる逸脱に対して、対策立案の必要性を同定します。そのために，事故のひどさと頻度を評価します。これら二つの評価が高いほど対策をとる必要性が高いといえます。表 2-7 に示したリスクマトリクスを利用して、評価を行います。

表 2-7 ： ANSI B11 のマトリクス

危害の発生確率 Frequency	危害のひどさ Severity			
	致命的 Catastrophic	深刻 Serious	中程的Moderate	軽微 Minor
確定的 Very likely	High	High	High	Medium
起こり得るLikely	High	High	Medium	Low
起こりそうにない Unlikely	Medium	Medium	Low	Negligible
起こり得ないRemote	Low	Low	Negligible	Negligible

ひどさと頻度は，それぞれ以下の4尺度で評価します。

ひどさ: そうした逸脱による事故の「ひどさ」です。

- 致命的：死亡に至る事故
- 深刻：事故の影響から回復は不可能。失明など
- 中程的：事故の影響から回復は可能。怪我や火傷など
- 軽微：応急処置で手当てできる程度

頻度：そうした事故（逸脱）がどの位の「頻度」で起こるかということです。

- 確定的：対象製品を用いるとき事故が常にかなりの頻度で起こる
- 起こり得る：対象製品を用いるときしばしば事故が起こり得る
- 起こりそうにない：事故あまり起こりそうにない
- 起こり得ない：事故がほとんど起こらない

5 既存の対策の有無確認：

対策が必要であるとされた事故に対して、すでに対策案が存在するか否かを認します。対策がとれていない事故に対して、対策を立案します。

次の部分は AMDHH を用いた事例研究について、説明します。

4 :事例

キックボード（図4-1）を例に、AMDHHの分析例を示します。

図4-1: 分析例の踏み台

1 五つの項目の適切さの明確化：

準備、使用、メンテナンス、保存、廃棄において、対象とする製品を用いるときの段階を決めます。ここでは使用段階をとりあげます。タスクは表4-1となります

表 4-1 ： 使用段階タスク

タスク（使用段階）
1-両手でハンドルをつかむ
2-右足か左足をまっすぐの状況でキックボードのスライドに乗せる
3-もう一方の足でこぎながら、運転する
4-こぐために使っている足でブレーキをかけて、キックボードのスピードを落とすか止める

図 2-1 で示した五つの項目について、タスクを実行するための適切な用い方を検討します。1 番目のタスクの実行場合のユーザーと環境項目だけの検討結果例を表 4-2 に示します。

表 4-2：適切な五つ項目

タスク（使用段階）	五つの項目	適切な五つの項目	
1-両手でハンドルをつかむ	ユーザ	主使用者：	6 歳以上の子供か大人
		副次使用者：	子どもの使用を助ける成人
	環境	濡れていない地面	
		明るい場所	
		平らな道	
		人の行き来する場所ではない	

2 適切な五つの項目からの逸脱の予見：

適切な五つの項目からの逸脱を予見します。1 番目のタスクの実行場合のユーザー項目だけの予見結果の例を表 3-3 に示します。

表 4-3：適切な五つ項目からの逸脱

タスク（使用段階）	五つの項目	適切な五つの項目		逸脱	
1- 踏み台をのぼる	ユーザ	主使用者	6 歳以上の子供か大人	主使用者	体重 90kg 以上の人
					怪我をしている人
					妊婦
					お年寄り
					幼児
		副次使用者	子どもの使用を助ける成人	副次使用者	きちんとハンドルを支えられない人：お年寄り、子供、身体に障害がある人

3 逸脱による事故の存在の確認：

次に各逸脱により、事故が生じうるかを評価します。1番目のタスクの実行場合のユーザー項目だけの評価結果の例を表4-4に示します。事故につながっている逸脱行為は隠れたハザード（Hidden Hazards）として考えられます。

表 4-4 ： 適切な用い方からの各逸脱の事故の存在の確認

タスク（使用段階）	五つの項目	適切な五つの項目		逸脱		逸脱により事故があるかどうか
1-両手でハンドルをつかむ	ユーザ	主使用者：	6歳以上子供か大人	主使用者：	体重90kg以上の人	ハンドルに負荷がかかり、ハンドルロックレバーが壊れ、転落する。製品が壊れ転倒し怪我をする
					怪我をしている人	上手に握れず、運搬中に足にボードを落とす
					妊婦	腹部を守ろうとして無理な姿勢でハンドルをつかみ、バランスを崩し、転倒する
					お年寄り	バランスを取れずに横転する
					幼児	しっかり握れず横転する
		副次使用者：	子どもの使用を助ける成人	副次使用者：	きちんとハンドルを支えられない人:お年寄り、子供、身体に障害がある人	支えることが出来ずバランスを崩して倒れる

- 事故を確認するときには、その事故が稀なことか、あるいは重大な結果をもたらすものか、ということは考えずに、できるだけ事故を見つけ出します。その後、評価のところにおいて、リスクを判断すれば良いのです

4 ひどさと頻度の評価：

Part2でリストアップした各事故に対して，表の2-7でひどさと頻度の評価を行って、対策を講じるべき隠れたハザードを明らかとします。1番目のタスクの実行場合、ユーザーの主使用者項目だけの評価結果の例を表4-5に示します。

表 4-5 ： リスク評価

タスク（使用段階）	五つの項目	適切な五つの項目		逸脱		逸脱により事故があるかどうか	ひどさ	頻度	結果
1-両手でハンドルをつかむ	ユーザ	主使用者：	6 歳 以 上 子供か大人	主使用者：	体重90kg以上の人	ハンドルに負荷がかかり、ハンドルロックレバーが壊れ、転落する。製品が壊れ転倒し怪我をする	深刻	起こりそうにない	Medium
					怪我をしている人	上手に握れず、運搬中に足にボードを落とす	中程的	起こりそうにない	Low
					妊婦	腹部を守ろうとして無理な姿勢でハンドルをつかみ、バランスを崩し、転倒する	致命的	起こりそうにない	Medium
					お年寄り	バランスを取れずに横転する	深刻	起こりそうにない	Medium
					幼児	しっかり握れず横転する	致命的	起こりそうにない	Medium

5 既存の対策の有無確認：

Part3 で、High と予見されたリスクについて、すでに対策が取られているかどうかを確認します。もしとられていなければ、対策を講じる必要があります。また、Medium, Low と予見されたリスクについても、対策が取られているかを確認し、もし対策が取られておらず、かつ、容易に対策がとれるのであれば、対策を講じることが望まれます。

対策例

- 保護機能・安全機能の装着
- 耐久性・信頼性の向上
- 注意喚起

早稲田大学　博士（工学）　学位申請　研究業績書

(List of research achievements for application of doctorate (Dr. of Engineering), Waseda University)

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（As of 7, 2018）

種類別	連名者（申請者含む）、題名、　発表・発行掲載誌名、　発表・発行年月
論文 （査読付）	1.　Hattan ATIYARE, Akinori KOMATSUBARA, Proposing of Analysis Method to Discover Hidden Hazards (AMDHH) at Consumer Products, Japan Industrial Management Association, Vol.67, No. 4E, 2016 2.　Hattan ATIYARE, Akinori KOMATSUBARA, Proposing a Method Named AMWAR (Analysis Method of the Worst Accidents Reasons) for Product Safety to Clarify the Worst Accidents Scenarios when Using Consumer Products, Japan Industrial Management Association Vol.66, No. 2E, 2015 3.　Kazumitsu Bonkobara, Hattan Altiyare, Akinori Komatsubara, A study on Risk Assessment Process based on Sabotage Analysis for the Safety of Consumer Products, Journal of Human Life Engineering, Vol. 13, p59-64, 2012/9
講演 （国際会議）	Hattan ATIYARE, Akinori KOMATSUBARA, AMWAR: Analysis Method of Worst Accidents Reasons, ISRERM (Reliability Engineering and Risk Management), Kanagawa University, Yokohama, Japan, Vol.3, p 33, 2012
講演 （国内会議）	1.　Hattan ATIYARE, Akinori KOMATSUBARA, Product Safety and Risk Assessment; Utilizing PDPC Method to Forecast Hidden Threats and their Consequences in order to Promote Products Safety, JES Japan Ergonomics Society conference, p1-2, 2013/6 2.　Hattan ATIYARE, Akinori KOMATSUBARA, Proposing an evaluation method of product safety based on sabotage analysis, JIMA, Japan industrial and management association, p18-19, 2013/5 3.　Hattan ATIYARE, Akinori KOMATSUBARA, Proposing a Predicting Method for the Accidents at the usage of Medical Devices based on Sabotage Analysis, the 52nd Conference of Japan Ergonomics society, p138-139. 2011 4.　Hattan ATIYARE, Akinori KOMATSUBARA, Proposing a Predicting Method for the Accidents at the usage of Medical Devices based on Sabotage Analysis, Kanto branch of Japan Ergonomics Society, p192-193, 2010