The Safety Hierarchy and Its Role in Safety Decisions

Kenneth R. Laughery[1], *Michael S. Wogalter*[2]

[1]Psychology Department
Rice University
MS-25, P.O. Box 1892
Houston, Texas 77251-1892, USA

[2]Psychology Department
North Carolina State University
640 Poe Hall
Raleigh, NC 27695-7650, USA

ABSTRACT

The safety hierarchy, or hazard control hierarchy, is a priority scheme for dealing with product hazards. It is often referred to as the design, guard and warn sequence. In order of preference, alternative designs that eliminate or reduce the hazard should be given first consideration. Where alternative designs are not feasible, guarding is the next preferred approach. Guarding can be viewed as an effort to prevent contact between the product user and the hazard. But like alternative designs, guarding is not always a feasible solution. Warnings are the third line of defense. Warnings are intended to provide information needed to use the product safely. Several issues and/or questions are explored regarding the application of the hierarchy to product safety. Examples are presented as a context for exploring some of the issues.

Keywords: hazard, safety, hierarchy, warning, design, guarding, strategy, control

INTRODUCTION

There is a concept in safety, as well as in human factors, engineering and other disciplines, known as the safety hierarchy, or alternatively the hazard control hierarchy (National Safety Council, 1989; Sanders and McCormick, 1993). This concept concerns a priority scheme for dealing with hazards. In this article we explore some of the issues associated with the concept as it is applied to consumer products. The basic sequence of priorities in the hierarchy consists of three approaches: first to design it out, second to guard, and third to warn.

If a hazard exists with a product, the first step is to try to eliminate or reduce it through an alternative design. If a nonflammable propellant in a can of hair spray can be substituted for a flammable carrier and still adequately serve its function, then this alternative design would be preferred. Eliminating sharp edges on product parts or pinch points on industrial equipment are examples of eliminating hazards. But safe alternative designs are not always available.

The second approach to dealing with product hazards is guarding. The purpose of guarding is to prevent contact between people and the hazard. Guarding procedures can be divided into two categories: physical guards and procedural guards. Personal protective equipment such as rubber gloves and goggles, barricades on the highway, and bed rails on the side of an infant's crib are examples of physical guards. Designing a task so as to prevent people from coming into contact with a hazard is a procedural guard. An example would be the controls on a punch press that require the operator to simultaneously press two switches, one with each hand, ensures that fingers will not be under the piston when it strokes. Another example is a physician's prescription for a medication. Without it, the medication cannot be obtained. However, guarding, like alternative designs, are not always feasible solutions for dealing with hazards.

The third line of hazard defense is warnings. Warnings can be thought of as safety communications. One of the purposes of a warning is to provide to people the information needed to make informed decisions about how to use a product safely, including the choice on whether to use it at all. Warnings are third in the priority sequence because they are generally less reliable than design or guarding solutions. Even the best warnings are not likely to be 100% effective. People at risk may not see or hear a warning, or they may not understand it. Further, even warnings that are seen and/or heard and understood may not be successful in motivating compliance. It is these reasons that warnings are the third strategy in hazard control, behind design and guarding. Influencing human behavior is often difficult and seldom foolproof. A short comment related to these points makes sense to mention at this point. These concerns about reliability should not be regarded as a basis for not warning when appropriate to do so. Rather, warnings are one tool available to product manufacturers and designers for dealing with product safety, and they have an appropriate role in the safety hierarchy.

There are other approaches to dealing with product hazards, such as

training (influencing how the product is used), personnel selection (influencing who uses it), and administrative controls (employer/supervisor sets and enforces rules). In the context of dealing with product hazards, these approaches are viewed as similar to warnings in that they mostly involve efforts intended to inform and influence behavior.

ISSUES ASSOCIATED WITH THE HIERARCHY

There are numerous questions or issues that may arise when applying the safety hierarchy. A starting point, of course, is to have a good understanding of the product hazards. While it is not within the scope of this short article to discuss the goals and methods of hazard analysis, there are two noteworthy points worth mentioning. The first point is that there are formal analytic procedures and/or tools for carrying out a product hazard analysis (Frantz, Rhoades, and Lehto, 1999). Examples of such procedures are fault-tree analysis and failure modes and effects analysis. Such procedures are widely recognized and practiced. A second point to note is that hazard analysis is, or should be, viewed as part of the design stage of product development. Hazard analysis ought to be carried out before it is made available to consumers. A product hazard that does not become recognized until the product has been in the marketplace can be costly both financially and with regard to safety outcomes. Recalls and retrofits are not a good substitute for timely and competent hazard analyses.

Once product hazards have been identified, whether through hazard analysis during design or through feedback after the product has been marketed (data about injury or health effects), the safety hierarchy comes into play in terms of decisions about how to address the hazards. In the following sections, we discuss some of the issues involved in such decisions.

Alternative Designs

The usually stated rule of thumb about when to implement an alternative design in dealing with a product hazard is "if a technologically and economically feasible alternative design is available, it should be implemented." Obviously the decision about whether to implement the alternative design is more complex than this phrase might imply. Clearly, alternatives must be technically possible, such as whether nonflammable carriers in hair sprays can be produced or whether there is a way to reduce automotive tire deterioration due to aging processes. But decisions about alternative designs must include consideration of issues such as the reliability and adequate function. If the alternative detracts from the effectiveness of the hair spray or causes the tire tread to wear faster, the alternative may not be an acceptable option, even though it addresses the hazard that led to its consideration.

It is also necessary to take into account economic feasibility is considering alternative designs. If the cost of eliminating a hazard with an alternative design is prohibitively expensive, it may not be an acceptable fix. Here again, however, the

economically feasible decision may be considerably more complex than meets the eye. Such considerations also are not within the scope of this article, but one factor that is sometimes suggested or considered, rightly or wrongly, and that is the potential cost of defending lawsuits based on safety issues associated with the product.

One additional point related to decisions about alternative designs is not so much a technological or economic issue. This point concerns the situation where an alternative design that eliminates the hazard is feasible on both technical and economic dimensions, but its implementation creates another hazard. Perhaps an example would be a nonflammable carrier for hair spray that is extremely toxic if it gets into the eyes. Likewise, the harm could be to the environment that could indirectly affect of health of users and others. The carrier in hairsprays used to be chlorofluorocarbons (CFCs), but these were found to negatively influence the ozone layer and increase greenhouse gases, and it was banned from use in the U.S. and some other countries. Obviously, alternative designs that create as many or more hazards as they solve is not the intent of the safety hierarchy. The decision to ban CFCs was made to reduce a societal, environmental hazard but resulted in an increased personal use hazard.

Some Factors that Influence Decisions

In the above section on alternative designs, a few factors were described that influence decisions about how to address product hazards. Technological and economic feasibility and the potential creation of other hazards were noted. There are other factors that can play a role in deciding how to address hazards. One factor is what the consumer wants or will accept; or alternatively, what the manufacturer believes the consumer wants or will accept. An example of this issue in the context of a consumer product will help make the point. Most vehicles marketed in the U.S. have front seats that can be reclined to a nearly horizontal position. (Pickup trucks with bench seats are an example of an exception.) It is generally agreed that it is hazardous for a passenger to have the seat significantly reclined to where the shoulder belt is not in contact with the torso while the vehicle is moving. The problem is that when the occupant is in the reclined position, the restraint system loses its effectiveness. Virtually all manufacturers now warn in the vehicle owner's manual not to recline the seat while the vehicle is in motion. While the quality of such warnings varies, the warning approach has been chosen for addressing the hazard—the third line of defense in the safety hierarchy. Studies show that most people are unaware of this hazard, although when called to their attention, people do understand it (Leonard, 2006; Leonard & Karnes, 1998; Paige & Laughery, 2003; Rhoades & Wisniewski, 2004). Laughery and Wogalter (2008) have explored the use of warnings to address this hazard.

But an alternative approach exists for addressing the seat recline hazard. Apparently it would be technically and economically feasible to design the seat so that it cannot recline to an unsafe angle. In terms of the safety hierarchy, it would be a preferred solution compared to a warning approach. The point here is that

vehicle manufacturers have taken into account at least two other factors in deciding to address the seat recline hazard with warnings. First, they considered a marketing factor based on the belief that customers want the seat recline feature. The second factor cited is that in circumstances where the driver is experiencing fatigue, it will be possible to rest by stopping and reclining the seat, a safety consideration.

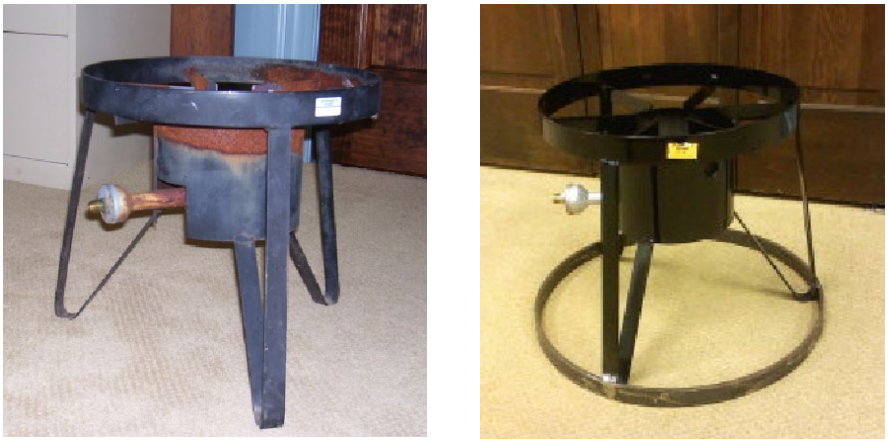
There is also a guarding approach that has been proposed for addressing the seat recline hazard. This approach involves a classic "kill switch," a name that is unfortunate as it simply means to turn off the power to the product or equipment. The point is that, the vehicle cannot be driven from a stopped condition if the seat is reclined beyond some safe angle, and if the engine is running, the seat will not recline. Note that this guarding solution permits the fatigued driver to stop the vehicle, recline the seat, and rest. Like the above design alternative, it is likely to be more successful than warnings in dealing with the seat recline hazard. Note that there may be other design solutions, such as designing the restraint system so it also works while in a reclined belted position.

Warning Versus Alternative Design Versus Guarding

The above seat recline example illustrates a product where the hazard is understood and there are options as to how to deal with it. More specifically, there is a choice between a technologically and economically feasible alternative design, or guarding, or warnings. Note that successful the design and guarding options need to be fail-safe, unless of course there is some kind of structural failure or successful effort to override the kill switch. The effectiveness of a warning option depends on the communications successfully informing and motivating the occupant not to recline the seat in the moving vehicle. The differences in effectiveness, of course, illustrate the underlying value or purpose of the safety hierarchy.

Another example of a consumer product where the safety hierarchy could or should come into play is a turkey fryer. The base or stand for such a fryer, or cooker, is shown in Figure 1(a). A large aluminum pot sits on top of the propane-fueled base shown in the figure. A typical application or use of the product would be to put cooking oil such as peanut oil in the pot and cook turkey parts or other meat.

Figure 1. (a) Poultry Roaster, (b) Modified Poultry Roaster



A significant hazard associated with this product is that it is unstable and can tip over if intentionally or unintentionally bumped or moved. The resulting hot oil spill can result in severe or catastrophic burns. Such incidents have occurred in situations such as outdoor picnics or similar events where children or animals may be active in the vicinity of the cooker.

The cooker comes with an owner's manual. The manual contains a warning that includes a statement that the hot oil can cause severe burns and advising to keep children and pets away. Note that the instruction to keep children and pets away is an example of a warning recommending a guarding solution. Our concern here is not to evaluate the adequacy or inadequacy of the warning. Rather, the intent is to explore how the tip over hazard could or should be addressed from the perspective of the safety hierarchy.

There are several design aspects of the turkey fryer that contribute to its instability. Included among these characteristics are: the width of its base, the height of its center of gravity, and the fact that it has only three legs. In terms of alternatives, these are design features that can be improved in ways that result in a significant increase in stability. For example, adding a fourth leg, lowering the center of gravity by shortening the legs, or adding a ring at the base of the legs as shown in Figure 1(b) are examples of design alternatives that are readily achievable.

A FEW SUMMARY COMMENTS

The examples of the vehicle seat recline hazard and the turkey fryer tip over hazard were presented as a context for exploring some of the kinds of issues encountered in deciding how to address product hazards. The safety hierarchy provides some principles and/or guidelines based on what is likely to be most effective; that is, the design, guard and warn priority scheme. But, as indicated with the seat recline example, decisions about whether to seek solutions based on alternative design, guarding or warning may be complex. In addition to technological and economic feasibility, factors come into play such as secondary safety effects and customer preferences.

Sometimes, however, the decision may be relatively straightforward, as (we believe) is the case with the turkey fryer. Clearly it does not require a revision of Newton's laws of physics to come up with a more stable cooker at what would appear to be a modest, if any, increase in cost. Certainly in comparison to a warning that recommends a guarding solution (keep children and pets safely away), the design alternative that increases stability would appear to be more effective. The point, however, is not to suggest that children and pets need not be monitored around the fryer or that a warning spelling out the potential severe burn consequences of a tip over is not appropriate. Rather the point is that guarding and warnings should be viewed as a complement to better, safer design, not as a substitute for it.

We end this paper with a comment on the complimentary aspects of the design, guard, warn safety hierarchy. The hierarchy should not be viewed as a priority scheme consisting of three options from which a selection can/must be made. Rather, it defines a preference scheme based on what is likely to be most effective from a safety perspective. It is not meant to imply some sort of exclusion principle; for example, if you guard (such as putting up a fence around a power station), that there is no need to warn (hang a warning sign on the fence that emphasizes danger and not to enter). Instead, the matter may be better thought of as: even with a better design, it may still be appropriate to guard or warn, or both.

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