A Benefit Cost Analysis on the Use of Fire Barriers in Upholstered Furniture*

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Chapter 1

Introduction to a Proposed Fire Barrier Standard for California's Upholstered Furniture

In 2014, California's Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI) amended its Technical Bulletin 117, concerning flammability standards of upholstered furniture intended for residential occupancy in the state (Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation [BEARHFTI], n.d.a). This amendment committed BEARHFTI to a further evaluation of its flammability standards through testing, research of fire resistant technologies, and the possible adoption of new regulatory standards as outlined in Technical Bulletin 117-2013 (BEARHFTI, 2015). Part of this ongoing review is a commissioned Benefit Cost Analysis (BCA) of the adoption of a fire barrier performance standard[1] for upholstered furniture, **which requires a flame-resistant fire barrier not chemically treated with flame retardants** to improve the resistance of upholstered furniture to an open flame (BEARHFTI, n.d.b). Such a BCA accounts for the likely benefits of the adoption of a fire barrier performance standard to the residents of California, and the likely costs to furniture manufactures of implementing it for home furniture sold in the state.[2] If the benefits exceed the costs, given a reasonable range of sensitivity analyses, then evidence exists regarding the efficacy of adopting such a fire-barrier regulation. Alternatively, if expected

[1] Performance standards only specify the minimum test requirements, and do not specify materials or manufacturer methods in meeting the standard (BEARHFTI, n.d.b). For the BCA, we need to assume the use of specific materials and manufacture methods.

[2] The likely benefits of which do not include the possible changes in health, and environmental impacts from decreased exposure to flame retardant chemicals. There are two primary reasons: (1) there is no clear policy mechanism that would cause a net change in overall levels of flame retardant chemicals when BEARHFTI does not regulate the use of flame retardant chemicals, and (2) the fire barriers under evaluation are non-flame-retardant cloth composite textiles (BEARHFTI, n.d.a). Thus, toxicity impacts from flame retardant chemicals are not a benefit addressable in this BCA.

benefits fall below projected costs, there is less justification for the adoption of this regulation. The following report contains the results of this BEARHFTI commissioned BCA.

This introductory chapter contains a history of concerns and institutions that led California to consider a fire barrier in upholstered furniture. Sections in this introductory chapter include: (1) the history of upholstered furniture regulation in California, (2) the economic logic of the possible need for government to require a cloth fire barrier in upholstered furniture, (3) the ignition sources and losses attributed to upholstered furniture fires[3] in the United States, (4) fire barriers used in upholstered furniture that fall outside of Technical Bulletin 117-2013, and (5) a conclusion that describes the remaining chapters in the full report.

Upholstered Furniture Regulation in California

In 1973, the National Commission on Fire Prevention and Control published a report on *America Burning* that brought increased attention to the concern of residential fires in the United States. Of the nearly one million building fires that occurred nationwide in 1971, nearly 70 percent of them occurred in residential buildings. Identified in this report was the underlying causal factor of the absence of any flammability standard for interior home furnishing. The prevailing regulatory sentiment at the time was that the choice of interior furnishings – as opposed to choice of structural building materials and standards regulated by building codes – was the sole responsibility of a residential occupant. But as noted in the Commission's (1973) report, a residential occupant can only fulfill this responsibility if in possession of adequate knowledge regarding the combustion hazards of interior furnishings. And even if knowing this, they must be able to process this knowledge. To put the latter into context, the Commission's assessment of the problem of residential fires in the United States from 1985 to 1994 found that half of all

[3] Upholstered furniture fires throughout the remainder of this report will refer to residential building fires where upholstered furniture is the first item to ignite, or as a primary contributing fuel source.

deaths caused by this had been due to sleep or intoxication while smoking on upholstered furniture (USFA, 1997). Since the Commission felt that adequate knowledge of this risk was not widespread and/or consumers were unwilling to engage in fire safe behaviors even if they possessed this knowledge, they recommended that the federal Consumer Product Safety Commission (CPSC) develop regulatory standards to minimize the combustion propensity of interior furnishings. Following this suggestion, in 1975 California became the first, and still only state to require flammability restrictions for residential upholstered furniture sold in its boundaries.

Technically, California adopted its restriction (Technical Bulletin 117) regarding a vertical open flame test from Federal Test Method Standard 191, Method 5903.2. This required the resilient filling materials (namely one-piece foam) used in home furniture to pass both a cigarette smolder test, and a 12 second exposure to an open flame test (BEARHFTI, 2000). In addition, shredded resilient filling materials needed fabric encasement that passed both a three second, and a 12 second open flame exposure[4] (BEARHFTI, 2000). The latter criteria being the result from expected fire behavior interaction between synthetic materials inherent in shredded resilient filling materials, and fabric used to enclose the filling materials. Absent federal CPSC action, and because a sizeable percentage of the country's furniture sales occur in California, Technical Bulletin 117 emerged as a *de facto* national standard for fire protection in upholstered furniture (Consumer Product Safety Commission [CPSC], 2016).

[4] This test method and its criteria came from an existing federal standard for children's sleepwear (Federal Test Method Standard No. 191 Method 5903.2.). Two different flame impingement times ensured the performance of varied materials. An all synthetic material exposed to a three-second flame may keep burning vertically upwards and exceed the six-inch char length failing criteria. The same material may pass the test if exposed to a 12-second flame impingement because the vertical plume can disturb the burning of the synthetic material causing it to extinguish prematurely the flames. The reverse may happen for materials made of natural fibers or blends.

Major elements of Technical Bulletin 117 remained relatively unchanged until 2012. In that year, California's Governor Brown asked BEARHFTI to review the bulletin considering growing concerns of the prevalent use of flame retardant (FR) chemicals in upholstered furniture to meet the 12-second open flame resilient filling material performance standard (California Legislative Information, 2014). While flame retardant toxicity concerns initiated the review of Technical Bulletin 117, the change to Technical Bulletin 117-2013 was predominantly the acknowledgement of inadequate flammability performance standards for upholstered furniture using only chemical retardants. BEARHFTI (n.d.b) indicated in its review of Technical Bulletin 117 that the original bulletin failed to meaningfully address: (1) smoking ignition hazards as one of the leading causes of upholstered furniture fires, (2) the role of upholstered cover fabrics as primary initial contact with an ignition hazard and its interaction with resilient filling materials, (3) National Bureau of Standards and CPSC studies finding insignificant differences between FR treated foam and non-FR treated foam, and (4) predominant role of cigarettes as ignition source in civilian deaths in residential building fires (see also BEARHFTI, n.d.c).

Technical Bulletin 117-2013 subsequently removed the requirement of open-flame ignition testing, and instead modeled the new cigarette smoking performance test standards based on the international ASTM E1353-08 aε1 standard (BEARHFTI, 2013). This standard prohibits specified component assemblies of furniture to: (1) smolder beyond 45 minutes, (2) exceed specified vertical char lengths specified per component assembly during the duration of the cigarette test, or (3) results in open flame combustion. Component assemblies within the scope of Technical Bulletin 117-2013 are the cover fabric, inter-liner (barrier) materials, resilient filling materials, and decking materials in upholstered furniture. If the resilient filling material and/or cover fabric fail the new cigarette performance test standard, then upholstered furniture must include an inter-liner barrier that passes the barrier materials test. The intent of Technical Bulletin 117-2013 is a reduction in the smoldering ignition of upholstered furniture for residential use, which remains its leading cause (BEARHFTI, n.d.a.). However, industry input during Technical Bulletin 117-2013's public comment review period suggested the absence of a standard to address the ignition from open flame sources underestimates this risk (BEARHFTI, n.d.a.). Currently, California's Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation is evaluating whether the use of flame-resistant fire barriers improve open flame resistance in upholstered furniture.[5] This BCA is an integral part of that evaluation.

Fire Barriers in Upholstered Furniture

The desirability of mandating fire barriers in upholstered furniture for home use requires a consideration of multiple factors. The first being whether the benefits from pursuing a regulatory requirement for upholstered furniture to contain a fire barrier capable of passing an open flame performance standard exceeds the costs of imposing it. The benefit of a reduction in upholstered furniture fires through the inclusion of a fire barrier stems from the incremental reduction in losses (deaths, injuries, and property loss) attributed to upholstered furniture in residential building fires once a fire barrier required. A reduction in the number and/or severity of residential building fires occurs if: (1) the fire barrier standard stops the ignition source from causing the residential building fire (see CPSC, 2016 using an analogous approach), and/or (2) a piece of upholstered furniture is less likely to be a primary contributing cause for a residential fire not started directly by upholstered furniture.[6] Considering that fire barriers have been shown

[5] Fire barriers represent a variety of cloth composites, and synthetic materials placed between the resilient filling material and the cover fabric (Davis & Nazare, 2012).

[6] We acknowledge the latter component does not strictly conform to past BCA research designs (see CPSC, 2016). Rather our BCA analysis, consistent with Hall's (2015) approach, will consider residential building fires addressable by a proposed fire barrier performance standard when upholstered furniture is a primary contributing fuel source.

to reduce peak heat release, slow fire spread, and overall reduce fire severity when upholstered furniture is exposed to an open flame (CPSC, 2012; Lock, 2016), there is a potential benefit from requiring them. But does the expected dollar value of these benefits exceed the costs of achieving them? A BCA can answer this.

However, before plunging into the details of such a BCA, there are underlying public policy factors to consider. First and foremost, is there a theoretical justification for the necessity of government involvement in trying to prevent fires started/accelerated by upholstered furniture? A core tenant of the economic approach to deciding when it is appropriate for government to intervene in what many would consider a free-market choice – between a consumer wishing to buy a piece of furniture for residential use and a manufacture wishing to sell it to them – is whether the consumer has all the information necessary to make an informed choice. Furthermore, even if the necessary information is available, can or will the consumer access it, and process it appropriately. If these conditions do not hold, economists label the market as exhibiting imperfect or asymmetric information. Because of this they point to the possibility that an improvement in the free market outcome could occur through third-party intervention, and correct this market failure (Bardach & Patashnik, 2016; Mintrom, 2012).

Imperfect information, arises when consumers lack the necessary information to ascertain differences between goods that affect the satisfaction they receive from consuming them (Hill & Myatt, 2010). In terms of flammability of residential furniture, if consumers do not know of differences in degree of flammability across furniture pieces, producers of less flammable furniture will not be able to sell it at the needed higher price to cover the additional costs to manufacture it. While producers of more flammable furniture can sell at the same price as the less flammable furniture, because consumers do not know of differences in the degree of flammability. Economists characterize this result as a form of adverse selection because the unfettered market results in the production and consumption of more flammable products (Hill & Myatt, 2010).

In the case of furniture sales, if knowledge of furniture flammability exists, the manufacture is likely to possess it for their own products through the ease of only testing a limited product line. While the consumer, without third-party testing like that conducted by an unbiased third party (e.g., *Consumer Reports*) or a government agency, will not possess accurate information on the flammability of all the residential furniture products available to them. Imperfect or asymmetric information leads to an increased risk of harm to the consumer that they are unaware of at time of purchase. The possible role of government intervention to overcome this asymmetric information is well established (Bardach & Patashnik, 2016).

Consumers are very unlikely to determine flame resistant differences between variations in fabrics, foams, and construction based on consumer tendencies to be unable to practice probabilistic reasoning, limited computational capacity, and limited attention (Congdon *et al.*, 2011). Similarly, the production and dissemination of adequate information to the consumer when voluntary, is also unlikely due to the cost of testing to the producer, and the problem of the consumer being able to verify (without independent certification) that the information is correct. Asymmetric information and adverse selection is certainly a risk in upholstered furniture markets, and the resulting propensity for increases in the severity and losses associated with residential building fires recognized as a reasonable concern since at least the federal Commission's (1973) report on *America Burning*.

Solutions to market failure and consumer harm from imperfect or asymmetric information often take the form of regulation through performance or licensing standards

(Bardach & Patashnik, 2016; Mintrom, 2012). The meaning of these is to ensure a minimum level of product safety to the consumer. But, this regulation generates the additional costs to taxpayers of government testing and enforcement; and greater material, labor, shipping and compliance costs to private furniture manufactures that are either passed forward to consumers in the form of higher prices, and/or backward to producers in the form of lower profits. Regulation at its worst can result in a form of government failure where the standard of regulation is set so high that the total social cost of government intervention exceeds the social benefits of rectifying a market failure (Mintrom, 2012).

Opposing views argue that a producer in an unregulated private market faces sufficient incentives to ensure adequate safety in their products. Critics of government intervention also point to industry associations who require safety assurances from its members (Shleifer, 2005). A relevant example is the Upholstered Furniture Action Council's long-standing development and adoption of fire-related test standards. And as mentioned earlier, if consumers really wanted to know about differences in the flammability of furniture for their home, would not the editors of *Consumer Reports* devote an issue to reporting on it?

Objective public policy analysis does not automatically align with the more politically liberal view that a market failure warrants government intervention to correct it. Nor does it align with the more politically conservative view that perceived market failures rarely exist, because industry associations and/or non-government consumer watchdog groups effectively deal with them. Instead, public policy analysis takes the perspective that if there is indeed a possible role for government to rectify a clearly denoted market failure, there must also be a level of objective justification before it occurs. Here, we have identified the legitimate public policy problem as the imperfect and/or asymmetric information that exists regarding the risk of civilian deaths, injuries, and property losses associated with inadequate information on open flame ignition resistance in upholstered furniture. And even if the consumer possesses this information, the inability of the typical consumer to process and act upon it appropriately still is likely. The central question of the benefit cost analysis offered here is whether this public policy problem is of sufficient magnitude that the expected benefits of government involvement in specifying an upholstered furniture barrier exceed the expected costs.

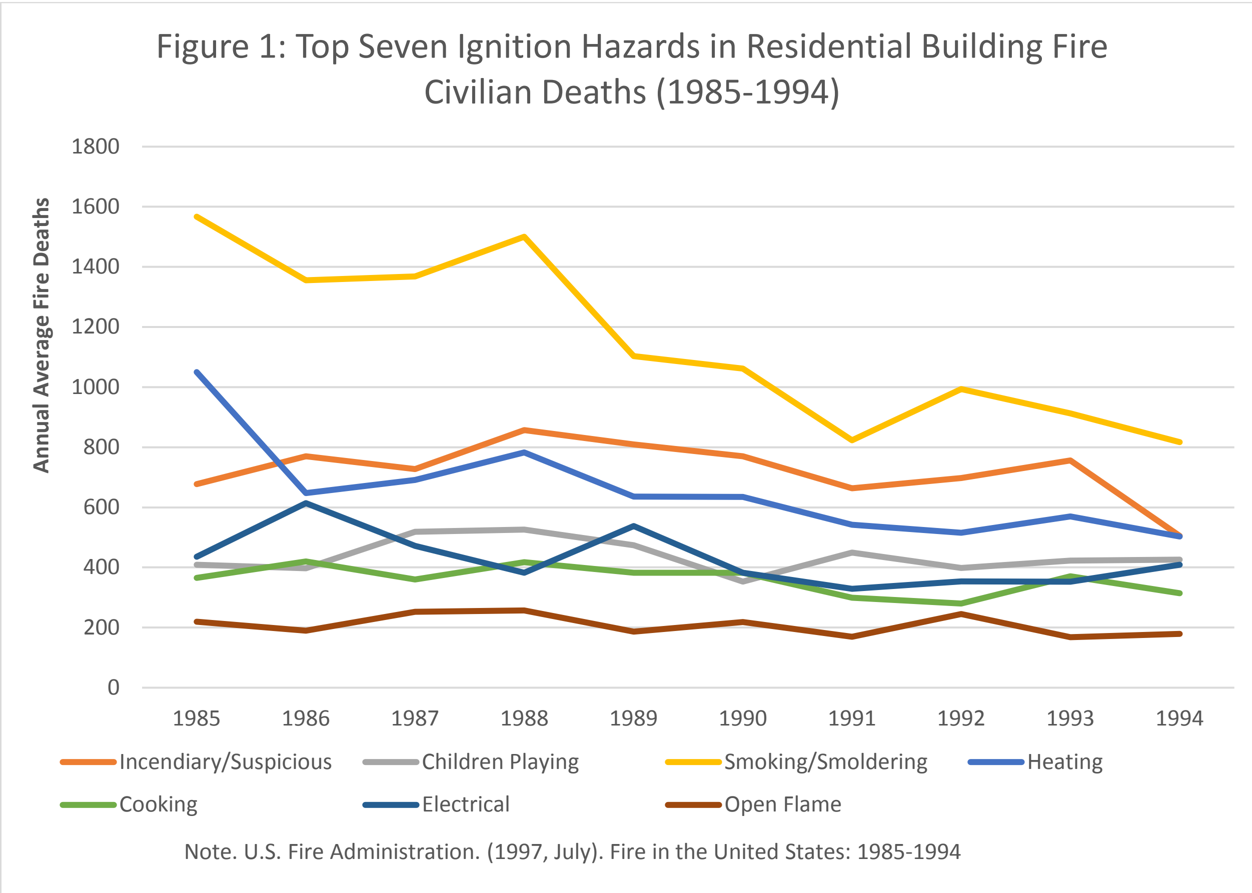
The Role of Upholstered Furniture in Residential Building Fires

As part of our BCA of a proposed fire barrier performance standard for California, it is necessary to ascertain the degree to which cigarettes and open flame ignition sources are the cause of residential building fires in the state. Combining this with an inventory of the magnitude of the civilian deaths, injuries, and property losses due to residential building fires, allows an estimation of the previous social costs inflicted by residential building fires due to upholstered furniture. A reduction of these social costs represents the benefits that fire barrier performance standard offers.

Yearly data from the National Fire Incident Report System[7] (NFIRS) offers a source of the needed information for the entire United States. The earliest summary of this data reported that residential building fires accounted for, on average in a given year between 1985 and 1994, 4,270 civilian deaths, 20,936 civilian injuries, and 4.2 billion dollars (adjusted to 1994 dollars) in property losses (USFA, 1997, p. 208). The leading cause of national residential fire deaths between 1985 and 1994 was cigarette ignition, with an annual average of 1,150 civilian deaths. While open flame sources consistently ranked as the seventh contributing cause, with a recorded annual average of 208 civilian deaths. As shown in Figure 1, cigarettes as a cause of civilian

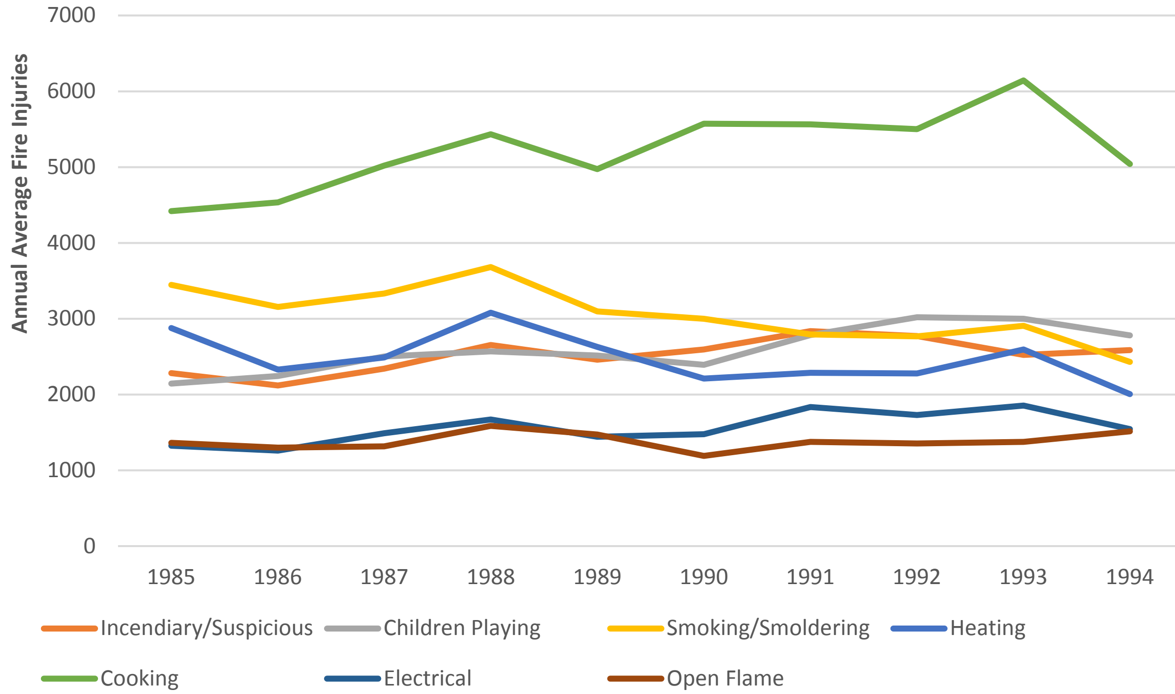
[7] NFIRS is a national database of U.S. fire departments reporting on a standardized range of fire related statistics.

deaths over this period exhibited a clear decreasing trend. In contrast, the proportion of civilian deaths attributed to open flame ignition remained relatively stable between 1984 and 1995.



For residential fire injuries, smoking ignition sources on average were the second leading cause with an estimated annual average of 3,061 civilian injuries. Similarly, open flame sources were the seventh contributing cause with an estimated annual average of 1,385 civilian injuries. Within residential fire civilian deaths caused by a smoking ignition sources, the leading reported cause is cigarettes dropped on upholstered furniture and mattresses (USFA, 1997, p. 208). In Figure 2, smoking ignition attributed to civilian injuries exhibited modest decreasing trend overall, with open flame ignition adhering to a small upward trend.

Figure 2: Top Seven Ignition Hazards in Residential Building Fire Civilian Injuries (1985-1994)



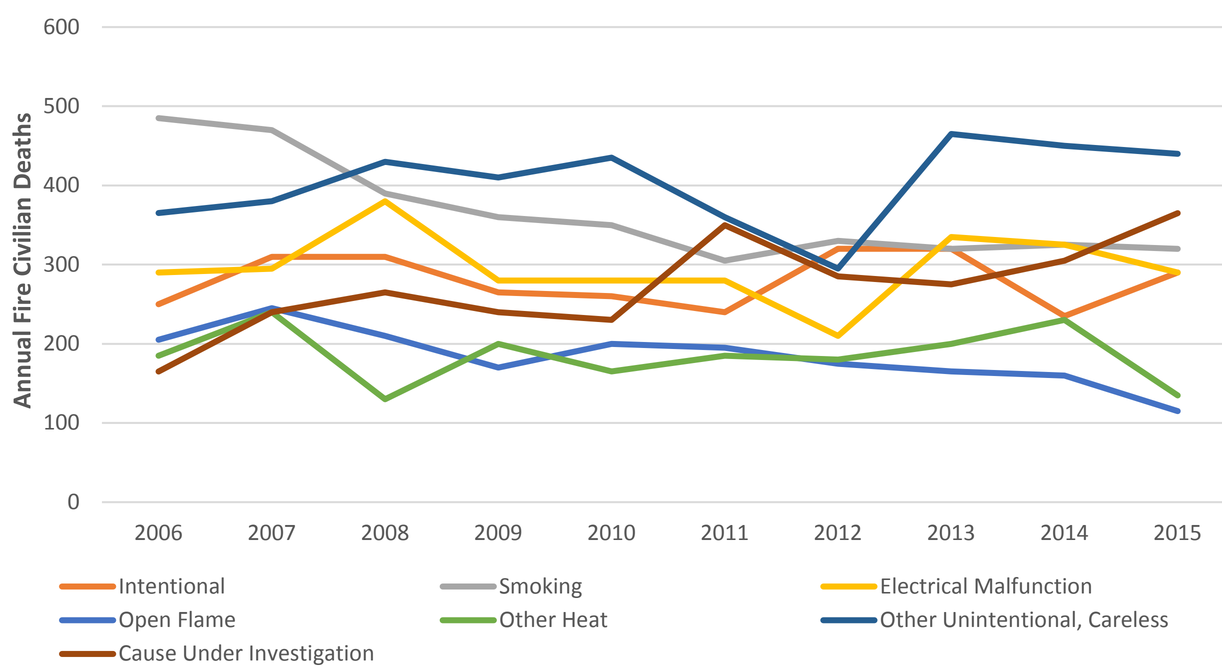
Note. U.S. Fire Administration. (1997, July). Fire in the United States: 1985-1994

For the more recent period of 2006 to 2015, using the same NFIRS data, residential building fires throughout the United States accounted for an estimated annual average of 2,586 civilian deaths, 12,800 civilian injuries, and 7.5 billion dollars (adjusted to 2015 dollars) in property losses annually (USFA, 2017). Comparing the ten-year averages from this more recent period to 1984-1995, both civilian deaths and injuries decreased 39 percent. Putting the average property loss for the period 1985 to 1994 in 2015 dollars[8], the average property loss would total an estimated 7.8 billion dollars (only slightly higher than found for the previous decade). Of the contributing factors of national residential fire deaths between 2006 and 2015, smoking ignition sources was on average the second leading cause with an estimated annual average of 366

[8] See http://www.usinflationcalculator.com.

civilian deaths. Open flame sources were on average the seventh contributing cause with an estimated annual average of 184 civilian deaths. Noted in Figure 3, both smoking and open flame ignitions as a cause of civilian deaths demonstrate an overall decreasing trend. This contrasts to the prior period of 1984 to1995 where open flame ignition failed to exhibit any meaningful long-term decreases.

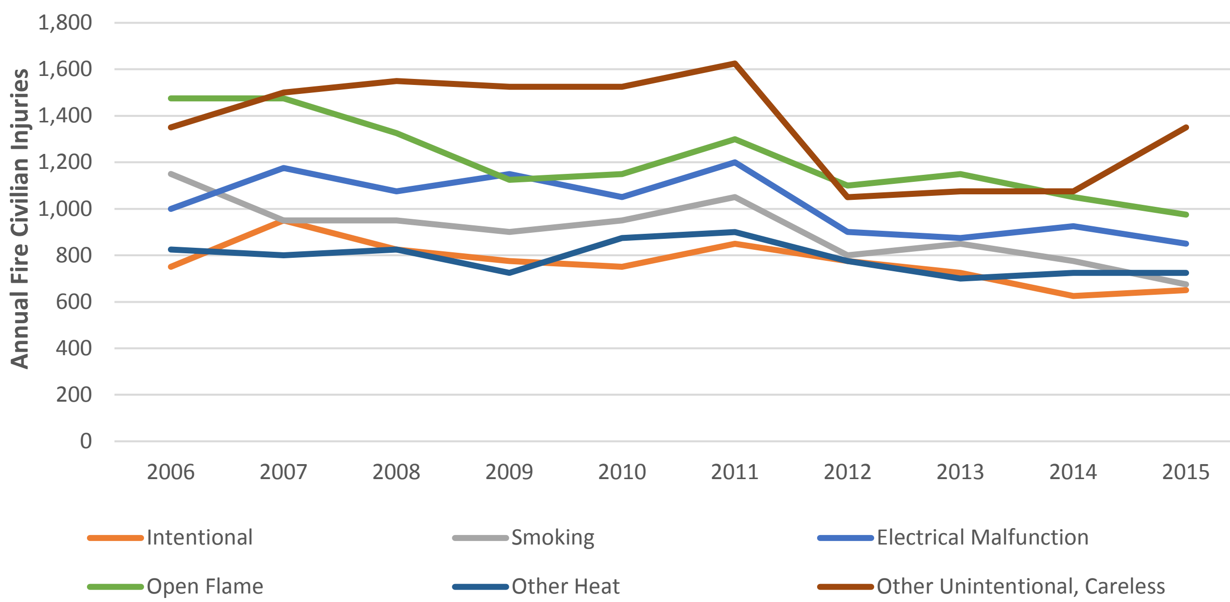
Figure 3. Top Seven Ignition Hazards in Residential Building Fire Civilian Deaths (2006-2015)



Note. U.S. Fire Administration. (2017, May). Residential Building Fire Trends (2006-2015

Regarding residential fire injuries, smoking ignition sources were on average the fifth contributing cause with an estimated annual average of 905 civilian injuries. In contrast to 1985 to 1994, open flame sources were the third leading cause with an estimated annual average of 1,213 civilian injuries. In Figure 4, both smoking and open flame ignition sources attributed to civilian injuries in residential building fires demonstrated decreases from 2006 levels (USFA, 2017). The 2006 to 2015 summary statistics do not report the role of upholstered furniture in residential fire civilian deaths.

Figure 4. Top Seven Ignition Hazards in Residential Building Fire Civilian Injuries (2006-2015)



Note. Cooking as the number one ignition hazard is not shown
U.S. Fire Administration. (2017, May). Residential Building Fire Trends (2006-2015)

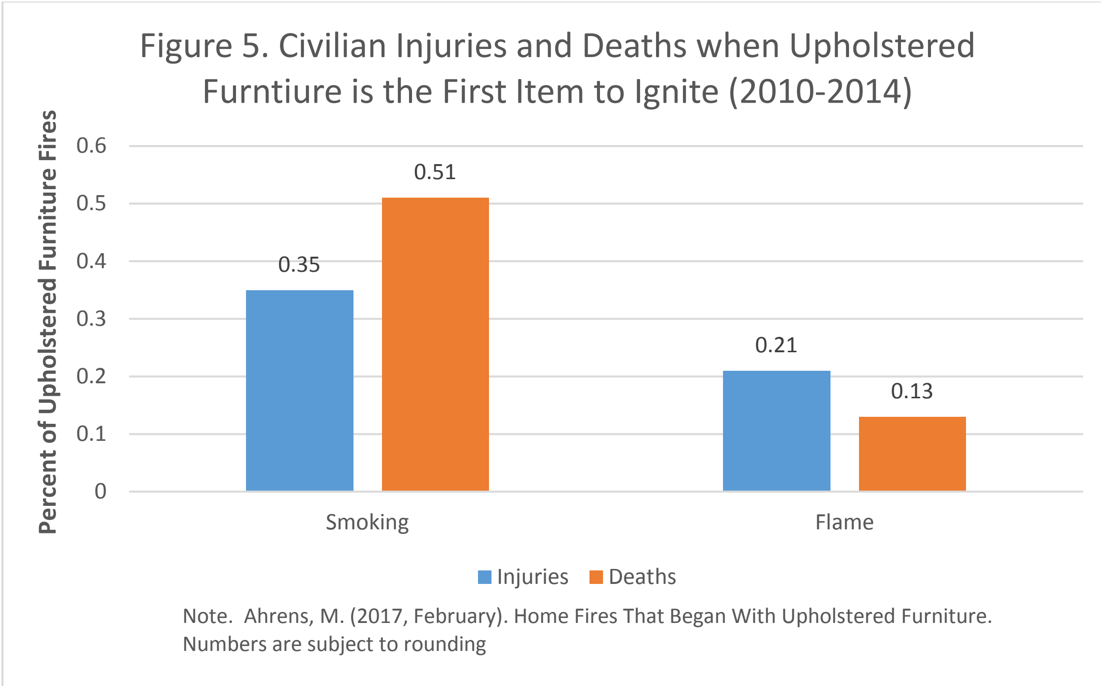
We note four important takeaways from comparing these two decade-long periods. The first being the continued property losses over the period examined. This demonstrates that residential building fires still exert significant costs upon the national economy. A second point is that smoking as an ignition source exhibits a continued downward trend in the estimated magnitude of national residential fire deaths and injuries. This is very likely due to: (1) a continued decrease in adult smokers, (2) public awareness campaigns on the dangers of falling asleep while smoking, (3) suggestions/requirement of smoke alarms in residential buildings, (4) and the adoption of ignition propensity standards for cigarettes in all states as of 2011 (Centers for Disease Control and Prevention, 2016; USFA, 2012; Hall, 2013). Despite these decreases relative to the earlier observed decade, smoking ignition sources are still a significant contributor to residential building fire deaths relative to competing ignition causes.

A third take away from the data is the resurgence of open flame ignition sources as a causal factor to residential building fire injuries. Lastly, both smoking and open flame ignition sources highlight the broader concept that smoking, and open flame ignition, clearly remain as hazards present in current residential building fires. While this does relate to upholstered furniture as potential ignition hazard, upholstered furniture is but one possible interaction with open flame and smoking ignition sources that contribute to residential building fires. Therefore, for the BCA offered here, it is important that we further examine the extent that upholstered furniture is a contributing factor in residential building property losses, deaths, and injuries.

A better understanding of the underlying contribution of smoking and open flame ignition of furniture to fire in residential buildings occurs through a more focused examination of national data sets from NFIRS, and the National Fire Protection Association's (NFPA) fire department experience survey. A combined data set of NFIRS and NFPA fire department experience survey for the period 2006 to 2010, lists upholstered furniture as the first item to likely ignite in residential building fires. Thus, during this more recent period, upholstered furniture was the primary cause of an annual average of 480 civilian deaths, 840 civilian injuries, and 464 million dollars (in 2015 dollars) in the United States (National Fire Protection Association, 2013, p. 3). Smoking ignition sources – defined as cigarettes and other lighted tobacco products – are the leading cause that accounted for about 28 percent of upholstered furniture fires as the first item to ignite. Whereas open flame ignition sources – defined as candles, matches, and lighters – accounted for nearly 22 percent of upholstered furniture fires as the first item to ignite. Furthermore, over the period examined, upholstered furniture ignition from smoking sources accounts for an estimated 57 percent of civilian deaths, and open flame ignition accounts for an estimated 13 percent of civilian deaths. Unfortunately, no data exists on civilian injuries caused by upholstered furniture as the first item to ignite within the sub-categories of smoking or open flame ignition sources (NFPA, 2013, p. 6).

Recent data from the 2010 to 2014 combined data set of NFIRS and NFPA fire department experience survey, shows upholstered furniture as the first item to ignite in residential building fires. As a result, it caused an average of 440 civilian deaths, 700 civilian injuries, and 269 million dollars (in 2015 dollars) in national property losses annually (Ahrens, 2017, p. 1). Smoking ignition sources – defined as cigarettes and lighted tobacco products – remain the leading cause accounting for an estimated 27 percent of upholstered furniture fires as the first item to ignite. Open flame ignition sources – defined as candles, matches, and lighters – accounted for 20 percent of upholstered furniture fires as the first item to ignite[9] (Ahrens, 2017, p. 22). Figure 5 shows the proportion of civilian deaths and injuries by ignition source when upholstered furniture is the first item to ignite.

[9] Data calculations use a five-year average from 2010 – 2014, and do not reflect per capita adjustment.



In terms of civilian deaths caused from upholstered furniture as the first item to ignite in a residential building fire, smoking ignition sources account for an estimated average of 51 percent of the civilian deaths, and open flame ignition account for an estimated average of 13 percent of the civilian deaths (Ahrens, 2017, p. 26). Concerning civilian injuries caused from upholstered furniture as the first item to ignite in a residential building fire, smoking ignition sources account for an estimated average of 35 percent of the civilian injuries, and open flame account for an estimated average of 21 percent of the civilian injuries[10] (Ahrens, 2017, pg. 22, 28-29). These estimates from the NFPA are in stark contrast to the limited estimates provided by the USFA on upholstered furniture as the first item to ignite in a residential building fire. Of all smoking ignitions, cigarettes caused about 86 percent of the time as causing residential building fires reported to NFIRS between 2008 and 2010. The initial item to ignite 13 percent of the time was upholstered chairs and sofas (USFA, 2012a). Unfortunately, the USFA in its most recent fire

[10] Data calculations for both civilian deaths and injuries use a five-year average from 2010-2014, and do not reflect per captia adjustment.

statistic publications do not include further upholstered furniture analysis (USFA, 2012; USFA, 2012a; USFA, 2016).

The cited USFA fire and National Fire Protection Associations (NFPA) estimates, derived from the National Fire Incident Report System (NFIRS) and supplemented by NFPA's fire department experience survey, are not estimates drawn from a random sample. Instead, these result from a tabulation reflecting around three-fourths of fire department through voluntary participation (Thomas & Butry, 2016). Subsequently, estimates derived from either data set warrant a level of caution. Among the limitations is the inherent sampling error involved in the NFPA's survey that only covers local fire departments, and NFIRS voluntary database. This further extends to differences in apportioning the magnitude of unclassified/unknown/not reported causes of residential fires to known categories. In addition, fire statistics contain an inherent level of measurement error. The accuracy of determining fire characteristics of any given residential building fire at the operational level changes based upon methodological definitions used to gather this data (USFA, 2012; NFPA, 2013; NFPA, 2016).

Understanding these limitations does not mean, however, that we cannot use the estimates produced by NFIRS, or supplemented by NFPA's fire department experience survey, to make reasonable approximations of the true population parameters concerning upholstered furniture statistics in residential building fires. For example, knowing about decreased smoking trends in the United States adult population, and passage of cigarette ignition propensity legislation in all 50 states, suggest an *a priori* expectation of further decreases in smoking ignition as a cause in residential building fires. The long-term smoking ignition statistics from NFIRS exactly demonstrates this.

NFRIS and NFPA's fire department experience survey data yield several conclusions relevant to the BCA offered here. First is the overall importance of smoking ignition sources as a cause of civilian deaths in residential building fires, and civilian deaths attributed to a residential building fire when upholstered furniture is the first item to ignite. Second is the persistence in smoking ignition sources. Cigarettes are consistently a predominate cause of upholstered furniture fires. While open flame as an ignition source factor in as an important secondary hazard when considering upholstered furniture as the first item to ignite. Third is the role of open flame ignition in causing civilian injuries from residential building fires involving upholstered furniture. While never the leading cause, it is sufficiently large to warrant inclusion in this BCA of upholstered furniture barrier regulation. Lastly, total property losses from residential building fires attributable to upholstered furniture as the first item to ignite, accounts for a much smaller subset of the total national property losses in residential building fires overall. However, if upholstered furniture as a principle contributor to flame spread in a residential building fire supplements the first item ignited, the estimates of average civilian deaths, injuries, and property losses respectively increase to 610 deaths, 1,120 injuries, and 615 million in inflated-adjusted 2015 dollars[11] (NFPA, 2013). Taking a more expansive view of property losses, civilian deaths, and injuries attributed to upholstered furniture as a contributing factor to a residential building fire is important, considering upholstered furniture total heat release potential and time to flashover (BEARHFTI, n.d.b ; Lock, 2016). Nonetheless, the small subset of total property losses attributed to upholstered furniture as the first item to ignite, or as a contributor to flame spread, does highlight the importance of needing further analysis as to the reasonable estimated benefits of further regulation of fire barriers in upholstered furniture in relation to the

[11] See http://www.usinflationcalculator.com.

estimated costs. Given the California specific framework for this BCA, data on property losses, deaths, and injuries attributed to upholstered furniture needs accounting for in terms of this state alone. Thus, we seek the most recent California data from the NFIRS and/or other sources. Regarding the NFIRS, this is possible because the office of the California State Fire Marshall currently reports to it.[12]

Applications of Fire Barriers in Other Regulatory Settings

When evaluating the potential need for a fire barrier performance standard in upholstered furniture, it is informative to examine whether the applications of fire barriers are effective in meeting other upholstered furniture performance standards. California's Technical Bulletin 133 (BEARHFTI, 1991) is a description of the most direct analogous use of fire barriers to meet upholstered furniture standards in this state.

Technical Bulletin 133, whose most current revision occurred in 1991, offers stringent flammability performance standards for upholstered furniture intended for non-residential (public) occupancies (NFPA, 2013). In public settings, upholstered furniture poses a significant hazard in the potential combined fuel load in any given room, which when ignited can release toxic levels of smoke, carbon monoxide, and accelerate the rate to flashover (Shields & Ohlemiller, 1995). To address these hazards unique to public occupancies, Technical Bulletin 133 achieves adequate flammability standards through a variety of mechanisms. First, the ignition source from a square gas burner replicates a large flame exposure (BEARHFTI, 1991). The alternative ignition source is five, double sheets, of black and white newsprint intended to replicate loose material common in public occupancies. Second, as argued by some (see Damant, 1995; and CPSC, 2016) the requirement of a full-scale fire test can be a more accurate

[12] See http://osfm.fire.ca.gov/cairs/pdf/cfirsresponseltr.pdf.

assessment of flammability performance over the approach of using individual components and composite assemblies. Third and perhaps most importantly, Technical Bulletin 133 requires that upholstered furniture for public use not exceed a maximum rate of heat release of 80 kW or greater (BEARHFTI, 1991). To meet these stringent flammability performance requirements, a predominant approach is the use of fire barriers to the allowable heat release standard (Damant, 1995; Shields & Ohlemiller, 1995).[13] Over a two-year test period in which BEARHFTI tested 500 upholstered furniture products, those with fire barriers met Technical Bulletin 133 performance standards with a 79 percent passing rate. Comparatively, upholstered furniture without fire barriers passed Technical Bulletin 133 performance standards only 61 percent of the time (Damant, 1995).

In the context of deriving useful conclusions from Technical Bulletin 133, it is important to note the limitations when using a comparative approach. The specific performance standards outlined in Technical Bulletin 133 do not generalize directly to proposed fire barrier performance standards intended for residential occupancies. The intent of Technical Bulletin 133 standards is to contain the rate of fire growth and severity of heat release, which is not analogous to open flame ignition resistance often considered in residential flammability standards (NFPA, 2013). Rather, Technical Bulletin 133 does provide an example where fire barriers are effective in mitigating a fire scenario of upholstered furniture ignition by another fire (NFPA, 2013). In residential occupancies, this fire scenario is particularly relevant when upholstered furniture can be a significant contributing factor to flame spread in residential building fires.

[13] Note, that although a large majority of manufactures uses fire barriers to pass TB 133, it is not a requirement. In principle, one can also use highly fire-resistant component materials (fabrics, foams, etc.) to pass TB 133 without the use of a barrier. The reality of this possibility is rare.

Unfortunately, beyond Technical Bulletin 133, we know of no other known examples of fire barriers meeting other upholstered furniture performance standards intended for residential occupancies. The CPSC proposed, but never adopted, a fire barrier standard for upholstered furniture in 16 CFR Part 1634 (CPSC, 2008). The only other known examples of fire barriers effectively meeting open flame performance standards are in mattresses (BEARHFTI, n.d.b; CPSC, 2006). The danger of using mattress to generalize to upholstered furniture is the two furniture products are not alike in geometry, design, decorative features, components, and construction (Lock, 2016). Regardless both Technical Bulletin 133 and mattresses demonstrate fire barriers are an integral part in meeting a variety of open flame performance standards in furniture.

What Follows

The chapter that follows contains a review of the literature relevant to completing the desired BCA of the use of non-chemical fire barriers in residential furniture in California. The third chapter of this report contains a description of the methodology behind our benefit cost analysis (BCA). While the fourth chapter of this report offers data used to complete the analysis, and the results of the BCA. The report wraps up with a final chapter of how robust/sensitive our BCA conclusion is to changes in the values of variables necessary to yield it.

Chapter 2

A Literature Review of Issues Relevant to a Benefit Cost Analysis of a Regulatory Fire Standard for Upholstered Furniture

The use of benefit cost analysis (BCA) to evaluate the efficiency of a regulatory fire safety standard for upholstery furniture is well established (see Muehlhause, 1978; Dardis, 1980a; Dardis, 1980b; CPSC, 2008; Jaldell, 2013; McNamee & Anderson, 2015). The benefits consistently calculated in such BCAs represent the incremental fall in societal cost from reductions in fire caused deaths, injuries, property, and content loss attributed to requiring the fire safety standard under evaluation. The expense of implementing the fire safety determines its cost. The BCA literature associated with a regulatory fire standard indicates that the enforcement costs, compliance costs, and incremental increases in manufacturing costs from the implantation of the standard are relevant[14] (Dardis, 1980b; CPSC, 2008).

The purpose of the following literature review is to offer better understanding of the information and methodology needed to conduct a BCA on the inclusion of fire barriers in upholstered furniture to meet a proposed fire standard. We divide this literature review into five relevant themes: (1) differentiation of product, (2) fire barriers and risk reduction, (3) product life cycle, (4) value of a statistical life and statistical injury, and (5) discount rate.

Differentiation of Product

Upholstered furniture, that exhibit homogenous flammability characteristics, allows the use of an aggregated average value for benefits and costs. Alternatively, upholstered furniture that exhibit

[14]Dardis (1980a) includes the loss of welfare from regulation as a societal cost of imposing a fire safety standard. In economic terms, this is the loss in consumer surplus and producer surplus from a furniture price increase that is greater in value than the loss occurred due to a price increase. It accounts for the fact that some people forgo the purchase of furniture after a forced fire barrier raises its price. We do not consider this loss in our later BCA for two reasons: (1) the necessary data to measure this is not available, and (2) Fuguitt & Wilcox (1999) recommend against including the change in social welfare in a BCA.

heterogeneous flammability characteristics requires average values per category, which then require a weighted aggregation to determine total benefits and costs across all furniture. The work of CPSC (2008) and Jadell (2013) offers examples.

Jadell (2013) evaluates the required installation of ceiling fire sprinklers as a means of reducing fire related deaths, injuries, and property losses in buildings that house the elderly. Underlying this BCA is the assumption that an apartment that houses the elderly exhibits homogenous flammability characteristics. Jadell notes that the available information on apartments offered little evidence of structural differences in materials (wood structure versus metal, etc.) that would suggest differences in apartment flammability. In contrast, the Consumer Protection Safety Commission (CPSC, 2008) examines the establishment of an open flame fire performance standard in upholstered furniture as a means of reducing residential fire related deaths, injuries, and property losses. An important allowance in this study is differences in flammability characteristics across types of upholstered furniture. To differentiate between upholstered furniture types, CPSC (2008) categorizes upholstered furniture by the type of upholstery cover material; including: (1) severely ignition prone cellulosics[15], (2) moderately ignition prone cellulosics, (3) low ignition prone cellulosics, (4) thermoplastics[16], and (5) leather/wool/vinyl coated. As Davis & Nazare (2012) note, such a categorization works because the material used in a fabric cover is a large determinant in upholstered furniture ignition. CPSC (2008) determines the total estimated benefits to society from an open flame ignition standard for severely ignition prone cellulosic material to range between $9.0 and $11.1 million. Alternatively, the same standard applied to upholstered furniture using thermoplastic cover

[15] Cellulosics are a synthetic derivative of cellulose; a natural occurring polymer from plant fibers.
[16] Thermoplastics are a synthetic plastic polymer that softens and melts at high temperatures, and hardens when cooled.

materials results in zero benefits to society. This deviates significantly from a homogenous assumption, which assumes the same range of benefits to all upholstered furniture.

The BCA application of the different cover fabric flammability characteristics used by CPSC (2008) required their own funded surveys (in 1981, 1984, 1995, 1997, 2001, and 2006), and further information from the Upholstered Furniture Action Council. To replicate this approach for the current upholstered furniture market would require the extensive use of industry surveys to determine the current distribution of cover fabric materials used in California's upholstered furniture market, or the use of broad estimates from representatives of furniture manufactures. In the absence of publically available upholstered furniture market data, our BCA will assume homogenous upholstered furniture flammability characteristics.

Fire Barriers and Risk Reduction

Central to a BCA that evaluates the desirability of a fire safety standard for upholstered furniture is the estimated incremental reductions in societal costs from deaths, injuries, and property loss likely to occur after the implementation of the proposed fire safety standard. Inherent in this estimation is knowledge on the effectiveness at reducing furniture flammability due to the proposed fire safety standard. We next offer a summary of the relevant literature on fire barriers, mechanisms used to achieve flame resistance, and fire barrier test findings. We follow this with a review of the methodology used to determine the resulting reduction in risk from each of these.

Fire barriers provide flame resistance in upholstered furniture by preventing or delaying flame propagation and limiting thermal penetration to the underlying resilient filling materials (Davis & Nazare, 2012). For the purposes of this study, we only consider flame resistance. This is an important distinction given that fire barriers that resist cigarette ignition resistance do not necessarily resist open flame ignition, and vice versa (Babrauskas & Krasny, 1985). The efficacy of fire barriers in providing flame resistance is largely dependent upon the fabric, and construction characteristics of the fire barrier (Davis & Nazare, 2012).

A fire barrier is typically an individual fabric component, or a fabric composite that takes on the form of individual or laminated layers (Davis & Nazare, 2012). The fabric components of an upholstered piece of furniture range from; (1) natural fibers like wool and cotton; (2) synthetic fabrics such as rayon (semi-synthetic), nylon, polyester; and (3) composites that can blend any number of fabric combinations with products like fiberglass (Damant, 1995; Davis & Nazare, 2012). How these fabric components relate to flame resistance depends upon whether the fabric will ignite, char, or melt/shrink when exposed to flame (Davis & Nazare, 2012). A fire barrier should not ignite unless ignition triggers a chemical release that induces flame suppression or flame quenching (Davis & Nazare, 2012; Davis et al., 2013). Even fire barriers that melt or shrink can compromise the integrity of the fire barrier, leading to flame exposure (gaps/holes) and significant thermal penetration to the resilient filling materials. Charring fabrics typically provide a physical barrier between an open flame and the resilient filling material. A char barrier can lower the heat release and reduce volatile gases that aid flame propagation. However, charring fabrics that are prone to oxidation, and lack char strength (brittle char formation) can lead to thermal and flame penetration of the fire barrier (Davis & Nazare, 2012).

The construction of fabric used as fire barriers is equally important. Woven, knitted, or nonwoven represents a categorization of different construction methods. All else equal, knitted fire barriers are the least desirable as they are more prone to split open under open flame exposure than woven or nonwoven fire barriers (Davis & Nazare, 2012). Comparing woven and nonwoven fire barriers, the open flame resistance properties depend significantly on the permeability and thickness of a fire barrier. Highly porous woven fire barriers allow greater thermal penetration through greater air/gas permeability. Similarly, low thickness (loft) fire barriers demonstrate greater thermal penetration and fire barrier deformation (weight loss). Conversely, low permeability and higher thickness (loft) fire barriers tend to demonstrate better flame resistance properties (Davis *et al*., 2013).

The usefulness of any given fire barrier is contingent upon many factors. This is complicated further when moving away from fire barriers as a separate component to consider, and instead evaluating the efficacy of fire barriers as a small-scale composite or full-scale assembly. For example, if the cover fabric is of a highly flame-resistant material, then a fire barrier would not have to achieve the same level of flame resistance to pass a fire standard compared to a cover fabric that is cigarette ignition resistant, but not resistant to open flame (CPSC, 2005). Most of the examination of the efficacy of fire barriers, therefore, employs full furniture testing, or small-scale composite assembly testing constituting of a frame, standard polyurethane foam, fire barrier, and standard cover fabric (see CPSC, 2005; CPSC; 2012, Davis *et al.*, 2013; Lock *et al.*, 2016). We next offer a limited review of previous findings on fire barrier performance to open flame exposure using small scale composite assemblies in testing (and not full furniture).

Davis *et al.* (2013) examines 19 different fire barriers using a small-scale composite assembly comprised of standard polyurethane foam per NIST specifications, fire barriers pinned to the foam, and a cover fabric composition of 77 percent rayon and 23 percent polyester. He subjects all of this to an open flame for 20 seconds. Unsurprisingly, most nonwoven high-loft fire barriers demonstrated lower heat transfers during the test period of 90 seconds with an average temperature less than 225 degree Celsius. In comparison, most of the thin woven and knitted fire barriers demonstrated an average thermal response over the test period above 225 degrees Celsius, with a fire barrier reaching a maximum of 300 degrees Celsius. To juxtapose the characteristics of the worst and best performing non-flame-retardant fire barriers in allowing heat transfer, consider fire barrier 19 that is a glass fiber woven construction with an average thickness of 0.3 mm allowing a total heat transfer of 70.3 total MJ/m^2[17]. Whereas, fire barrier 7 is a carbon fiber nonwoven construction with an average thickness of 7.2 mm, and a total heat transfer of 4.6 MJ/m^2. Fire barriers containing carbon and glass fibers with woven/nonwoven construction demonstrated the lowest peak heat release rates of less than 15kW/m^2[18]. All organic fiber based fire barriers with varying thicknesses were flame retardant treated (e.g. boric acid treated cotton fabric with nonwoven needle punch construction), but were the worst performing fire barriers with peak heat releases in excess of 100kW/m^2 (Davis et al., 2013).

Alternatively, the Consumer Protection Safety Commission (CPSC, 2005) evaluated the efficacy of fire barriers using a measure of mass loss of the standard polyurethane foam and varying significantly both the fire barrier and cover fabric combinations. CPSC tested over 1800 different composite assemblies, comprised of 41 different cover fabrics, and 14 woven/nonwoven fire barriers. The test involved an open flame application for 70 seconds and observation for 25 minutes. The finding being less than five percent mass loss of the foam in a highly dense (18.3oz/yd^2) ceramic woven fire barrier paired with 100 percent cotton velvet cover fabric. While nonwoven sheet barrier of significantly less density at an average density of 3oz/yd^2 paired with either 100 percent cotton velvet, or 100 percent rayon cover fabric, demonstrated over 25 percent mass loss of the foam in less than 10 minutes.

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[17] A joule is a standard unit of energy, which a megajoule (MJ) is a million joules. Thus, MJ/m^2 refers to the amount of energy transfer (heat) per meter squared of fabric.
[18] A watt is the rate of energy transfer. A watt is equal to one joule per second.

Both of the previous studies offer two relevant conclusions. First, fiber choice needs to demonstrate a level of inherent flame resistance properties to limit peak heat release (Davis *et al.*, 2013). This is consistent with the conclusion noted in Davis & Nazare (2012), where a fire barrier that incorporates a woven glass fabric yields lower average peak heat releases. Moreover, Davis & Nazasre (2012) indicate fire barriers that rely on low-loft polyester batting can increase the flammability of the composite assembly. In terms of time to flashover[19] (approximately 1000kW), limiting the total peak heat release of upholstered furniture is critically important for an open flame fire scenario. Second, regardless of fiber choice the fire barrier needs to have sufficient thickness and density to limit heat transfer to the underlying foam (CPSC, 2005; Davis et al., 2013; Davis & Nazare, 2012). The most flammable material to aid in flame propagation, and release of toxic volatile gases are resilient filling materials such as foam (CPSC, 2012).

While not all fire barriers provide the same level of flame resistance, the previous literature clearly concludes that fire barriers on average provide some additional level of flame resistance (see CPSC, 2005; CPSC, 2012; Damant, 1995; Davis & Nazare, 2012). To determine justification for whether the cost of achieving this level of flame resistance in upholstered furniture is justified by its benefits, one must determine the expected value of benefits if upholstered furniture provides greater flame resistance. In a BCA, these benefits equal the dollar value assigned to deaths, injuries, and property losses prevented by the imposition and enforcement of a fire barrier standard. The technical reference to this is a change in risk reduction probability. As shown next, of the existing BCA literature that evaluates the efficiency of fire safety standards, the approach to estimating risk reduction probability varies significantly.

[19] Flashover is the near simultaneous flaming ignition of all combustible contents in a given space. A peak heat release of 1000kw often defines a standard fire scenario (see Babrauskas & Krasny, 1985). However, the total peak heat release to create a flashover is dependent upon numerous factors such as dimensions of the room, fuel load, ventilation assumptions, etc. (Guillaume *et al.*, 2014).

Dardis (1980a) offers a BCA on the desirability of home smoke detector use and chooses a risk reduction probability of 0.45 (based on a personal communication with the National Bureau of Standards) for deaths in a home equipped appropriately with smoke detector. In simpler terms, 0.45 indicates that the appropriate use of smoke detectors reduced the number of deaths by fire in a home by 45 percent. While Jaldell (2013) offers a more precise approach in the evaluation of fire sprinklers in reducing elderly home fire losses by examining incidence data. Using United States home data from 2002 through 2005, Jaldell calculates that homes with fire sprinklers, as compared to homes without fire sprinklers, demonstrated a 100 percent decrease in fatalities, 57 percent fewer injuries, and 32 percent less property damage. Jaldell notes similar impacts to reduced deaths in United States fire statistics calculated from 2003 through 2007. Restaurants and bars with fire sprinklers decreased fatalities by 100 percent, residential homes by 80 percent, and warehouses and offices by 75 percent. McNamee & Anderson (2015) also use incidence data to estimate the risk reduction probability from flame retardant use in television fires. However, CPSC (2008) notes their findings may be circumspect given that data does not exist on upholstered furniture that complies with a fire barrier performance standard. CPSC (2008) instead made reasonable judgements when estimating risk reduction probabilities of 0.51 for severely ignition prone cellulosic material, 0.25 for moderately ignition prone cellulosic material, and zero for all other categories (p. 11722). This means an open flame standard for upholstered furniture results in a 51 percent reduction in societal costs attributed to severely ignition prone cellulosic material, and only a 25 percent reduction in societal costs attributed to moderately ignition prone cellulosic. If we assume that all upholstered furniture exhibits an average risk reduction probability based on the above distribution, an average risk reduction probability of 0.19 is reasonable for all upholstered furniture.

The lack of available incident data to approximate the risk reduction probability highlights a significant limitation inherent to a BCA of a fire standard applied to upholstered furniture. Moreover, the available BCA studies on upholstered furniture fail to mention the assumptions used regarding fire barrier characteristics when making judgements on the resulting risk reduction probabilities (CPSC, 2008). As just described, not all fire barriers offer the same level of flame resistance, and the predictive performance of any given fire barrier is determined by a complex set of factors. Therefore, the reported risk reduction probabilities noted in our BCA will also depend upon the judgements of fire experts and must rely not just on one value; but, take on a range of reasonably accepted values.

Product Life Cycle

As a general BCA principle, the full time horizon to consider is determined by the useful lifetime of the product under evaluation (Fuguitt & Wilcox, 1999). Specific to the study of fire barriers in upholstered furniture, CPSC (2008) notes the average life cycle of upholstered furniture is 16 years. Given an average use of a new piece of furniture being 16 years, it is important to know the year within this product life cycle that a benefit or cost occurs. The reason being that a benefit or cost realized later in time in the benefit/cost stream is worth less than one occurring sooner (Fuguitt & Wilcox, 1999). This represents the time value of money and refers to a $1 in the bank today, earning an annual interest rate of three percent, is worth $1.03 after a year. Hence, $1 received a year from now, is only worth about $0.97 ($1/1.03) because that is the amount put in the bank today that results in a dollar a year from now at a three percent annual interest rate. The costs of implementing a fire barrier standard largely occur in manufacturing it.

The benefits of a fire barrier standard only accrue after the furniture with fire barriers is placed in new homes or replace existing furniture not subject to the standard. This makes the calculation of benefits, not as simple as the calculation of cost. Next, we look to the previous work on this to see how these benefits appropriately accounted for.

The most simplified method regarding benefit realization is to assume that the benefits of a fire barrier standard occur in each year of the product's life cycle and remain constant. Thus, the same level of benefits realized in year one will be the same amount of benefits realized in year 16; with the need to discount the later years' benefits appropriately. This approach works fine for a single piece of furniture, but what about accounting for the imposition of a fire barrier standard across all furniture. As an example of how to do this, McNamee *et al.* (2015) use the simplified assumption of a product life cycle of 10 years for furniture.[20] Using this assumption, in any given year, society replaces 10 percent of existing furniture. It takes 10 years for all furniture in use to exhibit the desired fire resistance. Alternatively, CPSC (2008) utilizes a product population model to calculate the likelihood the upholstered furniture item would remain in use in years after purchase. This is a theoretically more accurate approach that is adoptable here. Unfortunately, CPSC reported no information on the detailed methodology underlying the derivation of their model.

Value of a *Statistical Life* and *Statistical Injury*

The value of a benefit cost analysis (BCA) pertaining to a fire safety standard is that it offers a comparable accounting of the likely benefits to society of the standard, to the likely costs of the

[20] If the setting of a fire standard for furniture raises the cost to manufacture furniture, and some of this cost passed onto the consumer in the form of higher prices, then it is reasonable to assume that replacement rate of furniture will decline. Thus, a more reasonable assumption may be to go above the 16 percent observed by CPSC (2008) and instead set it at 20 percent. This price increase may also result in the less affluent owning furniture without the fire-resistant standard for longer because the demand for such furniture in the resale market will fall, lowering the price of such unregulated furniture relative to the purchase of new furniture with the imposed standard.

standard. This accounting is only comparable if benefits measured in the same units as costs. The measurement of costs occurs in dollars. Thus, the issue is how to best place the measurement of the benefits of a furniture fire safety standard (lives saved, injuries prevented, property saved, etc.) in dollars. The benefit of property never lost is replacement cost in dollars. The dollar value to society of a life preserved, or injury prevented, is not so easy. But important to note when thinking about this is the concept of uncertainty in knowing exactly whose life saved, or injury prevented, due to the fire safety standard. The fire safety standard does not save any specific life, or prevent any definite injury, but reduces the likelihood of it occurring for all who own furniture falling under it. Economists have dealt with this issue by looking at what the typical person is willing to spend to reduce life and injury threatening risks (Fuguitt & Wilcox, 1999; Viscusi, 1993).

Central to any benefit cost analysis (BCA) of a fire barrier performance standard in upholstered furniture is the value that individuals place on reducing mortality and injury risk from upholstered furniture fires. Inherent in this process are two related, but distinct, valuations: that of a statistical possibility of death, and that of a statistical possibility of injury. How either valued depends upon the valuation concept used. The two concepts widely used are willingness to pay (WTP) and willingness to accept (WTA). WTP estimates elicit the maximum amount an individual is willing to pay for reducing fire related risks of death or injury. Whereas, WTA is the minimum amount of compensation an individual is willing to accept to bear fire related risks of death or injury (Fuguitt & Wilcox, 1999). The purchase of injury reducing devices (smoke alarms and air bags) yields values of WTP. Values of WTA can come from increased compensation in a labor market for increased chance of injury. Dependent upon the method chosen, valuation concept, and the characteristics of the population sampled, the empirical valuations of a statistical life and injury can differ significantly (Viscuis, 1993). Therefore, we next summarize key determinants of WTP and WTA estimates from a sample of the previous literature on this subject.

It is first important to clarify that BCA does not explicitly put a value on a specific human life. Instead it assigns a value to a statistical life based on what people are willing to pay to reduce their chance of death or injury. Through observation, this is not valued at infinity. Why; because people choose to not purchase an optional safety option for a product, even though it will reduce the chance of death or injury (optional side air bags in an automobile). Alternatively, people are willing to take on a job for higher pay (fire fighter) even though it offers a greater chance of death or injury.

Jaldell (2013) notes the growing body of literature to suggest that WTP varies depending upon the individual's perceived level of risk, and the familiarity of the specific risk context. Carlsson *et al.* (2010) asks 5000 respondents through a mail survey to evaluate their willingness to pay for risk reductions in traffic, drowning, and fire related deaths. Respondent's WTP for reductions in fire and drowning risk were one-third of that of automobile risk reduction. Savage (1993) also notes the degree of knowledge about the risk context produces a statistically significant lower WTP for reducing risk in domestic fires than that of stomach cancer, road, and aviation accidents. This does raise an important question on whether it is appropriate to use WTP estimates derived from different risk contexts that are unlikely to share the same level of perceived risk and respondent knowledge. For example, the CPSC (2008) study of an open flame standard in upholstered furniture relied upon the often cited five million dollars for the value of a statistical life based on extensive research using labor market data on increased compensation accepted to bear greater risk in an occupation (Viscuis, 1993). We point out here that it is reasonable to question the value of statistical life based entirely on labor market. There is the critical issue that those having a higher risk tolerance than society in general gravitate to more risky professions, and thus the compensation paid to them to bear the higher risk may not reflect what would be required for the typical person in society to do so.

The differences in the value of a statistical life calculated by type of valuation concept used are subject to debate (Fuguitt & Wilcox, 1999). Behavioral economics suggest WTP estimates are lower than WTA due to loss aversion (Congdon *et al*., 2011). Individuals on average perceive losses more intensely than gains, and accordingly place more value on the potential to incur a loss as measured by WTA (Congdon *et al*., 2011; Fuguitt & Wilcox, 1999). Cumming *et al*. (1986) reviews valuation studies and finds WTA estimates can differ upwards of 1.6 to 16.6 times WTP estimates. Alternatively, Kniesner *et al*. (2014) finds that employees in their labor market sample fail to demonstrate statistically significant differences between willingness to pay (WTP) for increased workplace safety, and willingness to accept (WTA) for less workplace safety. Despite the extensive economic literature in estimating the value of a statistical life, there is a lack of consensus as to the approach that best approximates the true population parameter for any given mortality risk reduction context. Thus, we briefly review all three approaches with a focus on the empirical strengths and weaknesses noted for each.

The economic theory underlying the approach of using labor market data to calculate WTA is the fundamental premise that risky jobs will command a compensating wage differential in the labor market (Viscuis, 1993). To estimate the compensating wage differential requires a hedonic wage regression model at the individual unit of analysis that holds constant education, experience, and other causal factors that also explain wages; and then can tease out average compensation needed to take on a unit increase in the chance of death or injury. The strength of this hedonic approach is the available data based on observable wage-risk tradeoffs in the labor market. However, the weaknesses specific to this hedonic approach are WTA changes from regression specification choices (differences in variables, linear, non-linear, and structural equation approaches), limitations in the available control variables for some labor market data sets (omitted variable bias), endogeneity bias, and inherent variance in WTA preferences (sample bias) across workers in any given sample used (Viscuis, 1993). Variance in WTA preferences based on the sample characteristics is especially relevant when factors like age and income/wealth substantially alter the value of a statistical life (Jenkins et al., 2001).

The alternative to the hedonic approach just described is to use revealed preferences of risk reductions in non-labor market data. The economic theory relied upon in doing this is that consumer choices in product markets reveal preferences on the tradeoff between risks and benefit (Viscuis, 1993). The strength of this approach is the risk context studied can reflect a closer approximation to the risk reduction context inherent in policy oriented benefit-cost analyses. For example, inherently related to a consumer's willingness to pay for a reduction in fire fatality risks, is the WTP to pay to have smoke detectors installed appropriately throughout the residence. The main criticism of this approach is consumer choices that reflect discrete safety decisions, such as purchasing a smoke detector, are less likely to reflect a consumer's total willingness to pay for safety. Therefore, economists often consider a non-labor, market-based value of a statistical life a lower bound value (Viscuis, 1993).

Lastly, contingent valuation is an approach that utilizes a hypothetical market scenario to estimate a respondent's willingness to pay for risk reduction, or the willingness to accept additional risk (Viscuis, 1993). It is a contingent valuation because of no requirement that the respondent puts any money toward her stated answer. To estimate the WTP, survey methods can range from directly asking respondents opened ended WTP question(s) for the avoidance of a specific risk (after given the annual chance of it happening) using a bidding schedule of dollar value or a referendum question that asks whether they would be WTP a specific amount (Fuguitt & Wilcox, 1999). The primary strength of contingent valuation is the ability to tailor the risk context without constraint from the availability of market data. However, the drawbacks to this approach stem from the primary use of a survey format. The weaknesses can include starting point bias, strategic bias, respondent's use of approximate values, inadequate simulation of a market experience, respondent comprehension of the survey tasks, and to the extent respondent answers reflect the absence actual market behavior (Viscuis, 1993).

Because the three methods of using WTP, WTA, or contingent valuation yield a range of values for a statistical life, Table 1 offers a summary of the values derived from researchers across all three valuation methods. The values for a statistical life reported here range from $1.1 million to $8.3 million, with average value of a statistical life at $3.7 million across all studies. In the context of what is widely held as an acceptable range of three to seven million (see CPSC 2008; Viscusi, 1993), 3.7 million is at the lower bound of the acceptable range.

Sunstein (2004) is critical of using a uniform range for the value of a statistical life for all BCAs, and instead believes in its contextualization based on the type of risk. If only accounting for fire mortality risk, the two values for a statistical life found in the previous literature are $1.4 million and $2.5 million.[21] While theoretically focusing just on fire mortality risk is desirable for this BCA of upholstered furniture, there is a level of uncertainty associated with relying on only two research studies. Moreover, this conflicts with guidance memos issued by federal agencies. The Office of Management and Budget in 2003 endorsed acceptable values of

[21] It is important to note that these dollar values for a value of a statistical life are in terms for the year calculated in. To apply them in a contemporary BCA, they would need to be in "real" (inflation adjusted) terms.

statistical life ranging from one to ten million (U.S. Department of Transportation, 2016). In contrast, the U.S. Department of Transportation (2016) states the value of statistical life to use for a transportation-based BCA as 9.6 million for 2016. While the U.S. Environmental Protection Agency notes their default guidance for the value of a statistical life as 7.4 million.[22] Thus, we must conclude that no single value provides the paramount estimate of the value of a statistical life; instead, it is best to take a sensitivity approach that accounts for how the use of a range of values influence the determination of whether the benefits of a fire standard for upholstered furniture exceed its costs.

[22] See https://www.epa.gov/environmental-economics/mortality-risk-valuation#whatvalue .

Table 1: Summary of Literature on the Value of a *Statistical Life*

Authors	**Sample Characteristics**	**Risk Context**	**Method**	**Valuation Concept**	**Value of a *Statistical Life* Used**
Gerking & Schulze (1988)	*Sample:* 2130 completed households surveys *Sample Characteristics:* controlled for age, income, race, gender, education, and if union member	Ranked job fatality risk	Contingent Valuation	WTP	3.4 million
Garbacz (1991)	Sample: Time Series data with interpolation from 1968 – 1985 Sample Characteristics: fire deaths per million households, income, price of medical care, cigarette consumption, population age, race, fire department spending, time trend, wood and alcohol consumed per household, risk factor	Fire fatality risks without smoke detectors	Non-Labor Market Data	WTP	1.4 to 2.5 million
Scotton (2013)	Sample: Panel data on 84,336 workers from the National Bureau of Economic Research's Merged Outgoing Rotation Group for year 2006 Sample Characteristics: risk factor, income, age, gender, marital status, education, location, industry, and occupational characteristics	Occupatio nal fatality Risk	Labor Market Data	WTA	8.0 million
Gayer et al. (2000)	Sample: 16928 households Sample Characteristics: housing hedonic characteristics, proportion under 19, race, school quality, year, education, tax rate, distance to superfund, risk factor	Cancer fatality risk from Superfund cite	Non-Labor Market Data	WTP	4.7 million
Kniesner et al. (2014)	Sample: Panel data (PSID) of 2036 men from 1993-2001 Sample Characteristics: job characteristics, location characteristics, age, marital status, race, work hours, income, risk factor	Occupatio nal fatality risk	Labor Market Data	WTA	7.7 million to 8.3 million
Carlsson et al. (2010)	Sample: 1900 completed household surveys in 2007 Sample Characteristics: household characteristics, income, city, education, smoke detector, experience with fire accident(s), risk factor	Traffic, Drowning , and Fire fatality risks	Contingent Valuation	WTP	Fire: 2.2 million Drowning: 2.1 million Road Traffic: 3.3 million
Jenkins et al. (2001)	Sample: Cross Sectional data from Consumer Reports and national population subgroups in 1997 Sample Characteristics: purchase price, population characteristics, time, disutility, risk factor	Bicycle fatality risk	Non-Labor Market Data	WTP	Age 5-9: 1.5 million to 2.7 million Age 10-14: 1.1 million to 2.6 million Age 20-59: 2.0 million to 4.0 million

The willingness of an individual to pay a dollar amount (WTP) to avoid bearing a non-fatal injury shares many of the same considerations and determinants just noted for the value of a statistical life (Viscusi & Aldy, 2003). In fact, research has shown the value of a statistical life for an individual is highly correlated with the value she places on a statistical injury (Viscusi & Aldy, 2003). Despite the similarities, it is worth noting several differences found in the literature regarding the methods employed to estimate the value to society of avoiding a statistical injury.

The cost of a statistical injury must reflect the value lost from lower quality of life, pain and suffering, and reduced income potential after the injury (U.S. Department of Transportation, 2009). As a result, the value of a statistical injury is highly sensitive to the risk and injury context (Viscuis, 1993). There are three approaches used to estimate the value of a statistical injury: WTP, interpolation, and damage cost. WTP often relies upon the previously described method of contingent valuation where and individual hears of the details of an injury and then offers, in various ways, the maximum willingness to pay to avoid the described injury.[23] A second approach, adopted by the U.S. Department of Transportation (2011), relies on interpolation based on the value of a statistical life. The justification for this being that WTP estimates are not possible over an entire range of disabilities that could occur for something like a burn injury. Thus, the basis for interpolation using fixed proportional factors is the Abbreviated Injury Scale (AIS) to calculate the value of a statistical injury. AIS is a global severity classification system that combines the body part(s), percent body surface area, and

[23] A poor person is much more likely to report a lower WTP to avoid a specific injury than one more affluent. This is no different from what occurs daily when the poor and affluent enter the same market to buy the same product. To overcome this inequity in reported WTPs, we could only rely on the higher end WTP values more likely reported by the affluent. The problem with adopting this higher end WTP for a BCA is that it makes the benefits of something like a fire regulation for furniture more likely to exceed its costs, and hence the implementation of the regulation. However, if the costs of such regulation result in higher furniture prices, the poor bear costs previously stated as not willing to pay for it. For this reason, we suggest an average WTP across income groups as the most appropriate.

injury severity to classify non-fatal injuries into five categories: AIS 1 (minor), AIS 2 (moderate), AIS 3 (serious), AIS 4 (severe), and AIS 5 (critical). For example, the assignment for a third-degree burn covering more than 50 percent of body surface area is a critical injury level of AIS 5, which is 59 percent of the value of a statistical life. The principle drawback of this approach is its reliance on the assumption that the value of a statistical life remains highly correlated with the value of a statistical injury, and that AIS weights are accurate estimators of the true population parameter for WTP for fire injury avoidance.

The third approach, damage cost, estimates the value of a statistical injury by aggregating the realized direct and indirect costs of a specific injury. Stacey & Smith (1979) only provided a framework for calculating the damage cost of non-fatal fire injuries as the summation of hospital costs, disability costs, rehabilitation costs, psychological costs, work loss costs, and legal costs. These costs further require adjustment by age, body part injured, and severity of injury. The CPSC employed a similar approach with a minor variation to include visitor transportation and lost earnings (Mcloughlin & McGuire, 1990). The strength of the damage cost method is that it relies on actual realized costs from non-fatal injuries. However, its notable weakness is the required access to detailed contemporary injury data. In the absence of this data, the limitation of using past estimates are significant because differences in costs for non-fatal injuries over time are explained by a variety of health care factors beyond just inflation.

Ideally a range of studies and methods for burns, anoxia, and other fire related injuries would be available for review. However, we found that there are only a limited number of previous studies devoted to estimating the value of a statistical injury from fire risks, and even fewer are applicable to injuries consistent with residential building fires (Viscusi, 1993). Using contingent valuation, Viscusi & Magat (1987) report an average respondent's WTP to avoid a hand burn at about $1 million. Conversely, the damage cost approach employed by CPSC (2008) indicates a national weighted average of around $150 thousand dollars for burns and anoxia injuries. While the interpolation approach indicates an AIS 5 injury consistent with third degree burns of more than 50 percent of the body surface, is 59 percent of the value of a statistical life. If a value of statistical life is $2.5 million, the value of statistical injury for a third degree burns is then $1.48 million. That is quite a range, which varies by a magnitude of ten, from $150 thousand to $1.5 million.

The disparity of injury values, and the lack of replicated research, presents a challenge in making objective conclusions. Instead of judging the accuracy of the injury values reported, it is more useful to examine which method better accounts for the distribution of non-fatal injury severities attributed to residential building fires. We cannot overstate the importance of the assumed distribution of injury severity when calculated a BCA for a fire standard applied to upholstered furniture. This is because, just on direct costs alone, the difference between burn severities can vary significantly. The U.S. Department of Transportation's (2011) AIS method best accounts for the injury severity distribution. After this review, we conclude that the AIS method allows for a full accounting of a large range of fire related non-fatal injuries which we can match with available incidence data specific to California to estimate a reasonable average value of a statistical injury.[24]

Discounting Rate

Inherent in any benefit cost assessment (BCA) is the requirement to discount future benefits and costs to obtain comparable values in present day terms. A dollar today has a greater value to an individual than the same dollar received in the future. And the value placed on that dollar given

[24] See http://www.mymedal.org/index.php?n=Military.290401 .

in the future is less and less as the time of the future period increased. Thus, any future monetary value, be it a benefit or a cost, needs discounting to its present values in order to comparably aggregate dollar values over a time horizon. Unfortunately, there is not a consensus on the exact discount rate to use (Fuguitt & Wilcox, 1999). What follows is a discussion on the merits of using either the social opportunity cost of capital or the social time preference rate as the basis of a discount rate, and the associated range of reasonable discount rates used in the fire related BCA literature and discount rate requirement specified by federal agencies.

A BCA of a fire barrier performance standard in upholstered furniture requires framing the discount discussion firmly in a public policy context (Fuguitt & Wilcox, 1999). The basis for using the social opportunity cost of capital is the perspective that public policy decisions represent forgone alternative investments of government funds. The discount rate can then be based on various real rates of return (i.e. adjusted for inflation) of public securities that share similar risk and duration characteristics to the public policy alternative. By extension, this approach requires directly relating the social return of public investment to returns generated by private investment. In economic theory, rates of return in perfect capital markets would align with the social rate of return of alternative public investments. Yet market distortions invariably create divergences between market rates, and the social rate of return of public investment (Feldstein, 1964). The rate of return paid on a public security is an imperfect proxy to a discount rate because they reflect macroeconomic factors, cyclical trends, uncertainty, and volatility. Therefore, most regard the social opportunity cost of capital as the upper bound of the true social discount rate (Moore *et al*., 2013). Alternatively, as noted in Fuguitt & Wilcox (1999), the social time preference rate offers a more accurate reflection of the social discount rate.

The social time preference rate is simply the collective willingness of society to forgo current consumption for future consumption (Fuguitt & Wilcox, 1999). There are two principle arguments that indicate the individual time preference rate is higher than society's time preference rate. First, society not only represents the collection of all current individuals, but future generations as well. When society evaluates the willingness to forgo current consumption for future consumption, it is more than just independent individual decisions to save, but a decision to save that considers the welfare of future generations. Second, preferences for future generations are unlikely captured in market behavior based on individual consumption. Since society reflects more than just individuals, society is more likely to discount the future at a lower rate (Fuguitt & Wilcox, 1999). Using a discount rate that measures society's preferences to save for future generations is more theoretically sound. The challenge resides in the lack of observed market behavior for this purpose. This has primarily led to three different approaches to determining the social time preference discount rate.

The first approach is purely normative and based on ethical considerations of future generations that argue for a zero or even negative discount rate (Tabi, 2013). This perspective presumes it is unethical to discount the wellbeing of future generations (zero discount rate), or that the wellbeing of future generations should deserve greater weight over the current generation (negative discount rate). A reliance on revealed preference is the basis of the second approach and generally employs the mathematical equation:

Social Time Preference Rate (STRP) = p + e*g ;

where (p) is the pure rate of time preference (value of current consumption over future consumption), (e) is the elasticity of the marginal utility of consumption, and (g) is the growth rate of per capita consumption (Tabi, 2013).

Finally, the third approach relies on stated preferences of surveyed individual when asked to choose between pairwise choices (now verses future), or through open ended questions (Tabi, 2013). Using any of these three approaches, the social time preference rate is generally less than the individual time preference rates observed in public securities (Fuguitt & Wilcox, 1999).

With a lack of consensus on whether the social opportunity cost of capital, or the social time preference approach best approximates the true social discount rate, an objective approach is to use a range of reasonable discount rates to determine if the conclusion regarding benefits verses cost of a fire standard is sensitive to the choice of discount rate. Therefore, it is necessary to derive a range of discount rates from a review of the peer reviewed economic literature, applied BCA studies, and federal agency applications. Table 2 offers a summary of discount rates previously calculated using both the social opportunity cost of capital and social time preference rate. As noted in the table, the social discount rate falls between 2.6 and 8.0 percent. Interestingly, our review of the BCAs discussed earlier as relevant to a fire safety rule for upholstered furniture, used a similar range of discount rate values. CPSC (2008) and McNamee et al. (2015) reported the widest range of discount rates. Respectively determining the sensitivity of their findings to three and seven percent discount rates, and a three and 10 percent discount rates. Dardis (1980b) only considered a discount rate of 10 percent, whereas Jaldell (2013) restricted the analysis to only a three and four percent discount rate.

At the federal level the BCA guideline set forth by the Office of Management and Budget suggests a single discount rate of seven percent for BCA. The Environmental Protection Agency (2016) expands the discussion of discounting further to specify a three percent discount rate on the basis of the alternative rate of return of government backed securities, and a seven percent discount rate if using the opportunity cost of capital. Overall the distribution of discount rates reported suggests three conclusions for the selective sensitivity analysis. First, the range of discount rates for the upper bound is between six and ten percent, with a consensus of seven percent. Second, the range of discount rates for the lower bound is between 2.6 and three percent, with a consistent use of three percent. Therefore, a reasonable sensitivity analysis to use in a BCA is discount rates of three, five, and seven percent. With the possibility also of noting the change in the BCA finding if the future receives no discount relative to the present.

Table 2: Literature Review Summary of the Discount Rate

Author(s)	**Valuation Concept**	**Method**	**Average Discount Rate**
Moore *et al.* (2013)	Social Time Preference Rate	Revealed Preferences	2.6 – 5.4%
Tabi (2013)	Social Time Preference Rate	Stated Preferences	2.9 – 5.0%
Kula (1984)	Social Time Preference Rate	Revealed Preferences	5.3%
Burgess & Zerbe (2011)	Social Opportunity Cost of Capital	Rate of return on U.S. non-financial corporate sector	6.0 – 8.0%

Conclusion

As identified in this review of the literature, there is no single approach to addressing the major BCA themes regarding: (1) differentiation of product, (2) fire barriers and risk reduction, (3) product life cycle, (4) value of a “statistical life” and “statistical injury”, and (5) discount rate. Underlying the disparity in research approaches to BCA is the challenge in applying theoretical concepts to existing data. The concept of heterogeneous flammability characteristics of upholstered furniture is more theoretically accurate but given budgetary resources and feasibility of gathering market data, the simplifying assumption of homogenous characteristics might be necessary. This challenge further extends to the value of statistical injury, product life cycle adjustment, and risk reduction probability. The risk reduction probability forms the basis for estimating the benefits in reduced societal costs of upholstered furniture fire related deaths, injuries, and property damage. Underlying any risk reduction probability requires assumptions about the future distribution of fire barriers in upholstered furniture, where currently existing data is lacking. As assumptions are necessary in BCA, to inform decision makers the requirement to explicitly state assumptions and outline the subsequent impacts to the analysis becomes necessary. Moreover, in line with objective analysis we do not shy from long standing economic disagreements on the reasonable value of a statistical life and the appropriate discount rate. Therefore, to avoid unduly influencing the BCA analysis we conclude that sensitivity analysis be adopted to demonstrate whether the benefits exceed the costs of a fire safety standard for upholstered furniture under a variety of value of statistical life and discount parameters drawn from the previous literature.

Chapter 3

Methodology and Model Specification Used for a Benefit Cost Analysis of a Regulatory Fire Standard for Upholstered Furniture

As described earlier, a benefit cost analysis (BCA) of California's proposed fire barrier standard for upholstered furniture requires an accounting of both the benefits to the consumers of these products and costs to the producer if implemented. Formerly stated, the benefits are the incremental reductions in residential fire caused civilian deaths, injuries, and property loss because of the standard. Whereas costs arise from the incremental increase in testing, compliance, financing, manufacturing, and state enforcement costs from implementation of the standard. As previously outlined, the challenge to operationalizing this is bridging the existing methodology in previous research to existing data sources that inherently limit the scope of some methods. We next describe the assumptions and methods used in our BCA to do this. We divide this description between issues relevant to first the benefit side of the analysis, and second to the cost side of the analysis.

Benefit Considerations

To generate the necessary monetary estimates of the benefits from reducing upholstered furniture fires in residential structures, it is first necessary to understand the magnitude of fires in California attributable to this cause. We do this by considering a subset of residential building fires[25] in California addressable by the proposed fire barrier safety standard involving upholstered furniture. The incidence of these comes from the National Fire Incident Reporting System (NFIRS) data specific to California in years 2010 through 2016. The use of this subset of NFIRS data requires the establishment of a baseline based upon the following criteria of: (1)

[25] Residential consists of single and multi-family, manufactured, mobile, and duplex dwellings.

fire origin (2) exclusion of intentional/arson fires and (3) case wise deletion of unknowns on heat source and item first ignited (NFPA, 2013; CPSC, 2016).

For the first criterion of fire origin, we restrict the area of fire origin – as categorized by NFIRS 2015 Reference Guide[26] – to the dining room, common room, den, family room, living room, lounge, bedroom, music room, recreation room, sitting room, basement, garage, carport, other functional area, other structural area, and other area of fire origin. Using this baseline, we identify two fire scenarios addressable by the proposed fire barrier safety standard: (a) upholstered furniture as the first item to ignite by an open flame source, and (b) upholstered furniture as the material contributing most to flame or fire spread. In the fire scenario (a), we use the category of upholstered furniture as the first item to ignite. This choice of first item is different from non-upholstered chair, bench, wooden furniture, appliance housing, and other furniture categories. We purposefully do this because it is unknown whether fire departments treat the other furniture category as well-defined furniture items that do not fit the other listed categories or as an unknown category when the furniture not identified. NFPA (2013) concludes that without further assessment of how fire departments interpret this category, it is not possible to know what percentage of upholstered furniture items fall under other furniture. We take the conservative approach by excluding the other furniture category in the primary analysis, and later evaluate the impact of inclusion through a sensitivity analysis. Consequently, there are fewer counted residential furniture building fire caused, property loss, deaths, and injuries in the primary analysis. Of the cases identified as upholstered furniture as the first item to ignite, we then classify cases resulting from open flame ignition – heat sources defined by NFIRS categories of matches, lighter, candle, flame used for lighting, and heat from other open flame

[26] See https://www.usfa.fema.gov/downloads/pdf/nfirs/NFIRS_Complete_Reference_Guide_2015.pdf .

sources. Noteworthy is that the inclusion of other open flame heat sources has no impact on our calculation of civilian deaths or injuries. This process accounts for part of the number of civilian deaths, injuries, and total property loss addressable by the proposed fire barrier standard for upholstered furniture.

Fire scenario (b) carries over the same methodology with three exceptions. First, and foremost, is the need to identify which residential building fires exhibited significant flame or spread of fire (fire spread). Adopting the approach outlined by Hall (2015), we use fire spread categories listed as confined to room, floor, building, and beyond building of origin. Secondly, we then classify these residential building fire cases by upholstered furniture items contributing most to flame or fire spread. To avoid double counting, we exclude cases also identified as upholstered furniture as the first item to ignite. This distinction identifies only residential building fires where upholstered furniture is not the first item ignited, but as the principle material contributing most to fire or flame spread. We include this second set of residential building fire cases, because upholstered furniture not engineered to resist ignition from open flame sources, but ignited from another item, is still a contributing factor in total heat release potential and time to flashover (Hall, 2015; Lock, 2016). The third exception is the use of ignition sources. Given that upholstered furniture may not be the first item to ignite, we expand the allowable list of ignition sources to include open flame, smoking materials, operating equipment sparks/heat, hot or smoldering objects, static discharge, multiple heat sources, and other heat sources. We then aggregate both fire scenarios to form the total annual property loss, civilian deaths, and injuries addressable by the proposed fire barrier standard for upholstered furniture.

With this aggregated fire data, we then derive monetary valuations that represent the total societal costs from residential upholstered furniture fires. The most straightforward valuation is property loss – measured as the loss in property and contents of the home – in nominal dollars. A monetary value for civilian deaths requires the use of a statistical value of life. Both Jadell (2013) and Savage (1993) find the willingness to pay for risk reductions of fire related deaths to be statistically lower than those used in transportation, health, and environmental applications. Garbacz (1991) reports estimated values of a statistical life for fire fatalities between 1.4 million and 2.5 million in 1985 dollars. Accordingly, we take these lower and upper bound estimates and inflation adjust them to 2017 dollars using the national CPI index to yield a minimum of $3.3 million, and maximum of $5.8 million. We then multiply this range of values for a statistical life by the expected number of civilian deaths saved after a proposed fire barrier standard in place.

To estimate the monetary value for civilian injuries, we accept the Department of Transportation's (2011) method of interpolating the value of a statistical injury from the value of a statistical life. This approach is particularly relevant when there are minimal WTP studies on the range of fire injuries for an average residential building fire. Based on the severity of injury, a fixed proportion of the value of statistical life yields the corresponding value of a statistical injury. The varying severity of injuries and the corresponding injury factors is based on the Abbreviated Injury Scale (AIS). AIS is a global severity classification system that combines the body part, percent body surface area, and injury severity to classify non-fatal injuries into five categories: AIS 1 (minor), AIS 2 (moderate), AIS 3 (serious), AIS 4 (severe), and AIS 5 (critical). For each AIS category there is a fixed proportional factor of the value of a statistical life that represents the average value for the range of injuries that fall within each AIS category

(U.S. Department of Transportation, 2009). For this BCA, we map the range of reported injuries that occur from residential upholstered furniture fires to the corresponding AIS categories. However, due to a lack of publicly available fire injury publications, we use the NFIRS 2013-2015 report on civilian fire injuries in residential buildings as a proxy for upholstered furniture fires in California (USFA, 2017). In other words, we assume the injury profiles in residential building fires is mostly indifferent to causes and ignition sources, and the proportion of injuries do not change substantially from year to year.

USFA (2017) attribute an average of 40.9 percent of civilian injuries to smoke inhalation, 6.2 percent to breathing difficulty or shortness of breath, 24.1 percent to thermal burns, 13.1 percent to combined thermal and inhalation injuries, and 15.7 percent attributed to other symptoms not associated with fire caused injuries. The reported body parts affected is 25.1 percent to the upper extremities, 11.3 percent to multiple body parts, 8.7 percent to the lower extremities, and 54.9 percent to all other body parts (USFA, 2017). To make reasonable judgements about assigning fire injuries to an AIS score, we combine AIS trauma scores for listed injuries, NFIRS body part data, burn body surface area percentages, and basic medical knowledge.

Smoke inhalation injuries (independent of smoke inhalation caused deaths) without serious thermal and chemically induced damage to the respiratory tract are generally not life threatening with proper treatment.[27] A first responder is likely to deliver oxygen into a fire victim's respiratory track through nose/mouth/throat, and observation follows at a hospital. If carbon monoxide poisoning is a factor, then the patient undergoes hyperbaric chamber treatment[28]. Based on this, we surmise that smoke inhalation injuries most likely receive an AIS

[27] See https://www.webmd.com/lung/smoke_inhalation_treatment_firstaid.htm#1 .
[28] See https://www.webmd.com/lung/smoke_inhalation_treatment_firstaid.htm#3 .

score of two. We find this analogous to other AIS 2 injuries, such as large lacerations, or compound factures to the digits that would also require hospitalization for non-life-threatening treatment[29]. We assume, furthermore, that breathing difficulty is a subset of smoke inhalation, and associated with significant direct damage to the respiratory tract. This form of injury can require immediate intubation, and predispose individuals to complications.[30] This subset condition of smoke inhalation should receive an AIS Score of a 3, which reflects an assumed more serious nature of this condition. Thermal burns AIS scores are heavily dependent on the percent of body surface area (BSA) – the greater the BSA, the greater the score. The AIS scores for burns are as follows: second and third degree burns between 10-20 percent BSA receive an AIS score of 2; second and third degree burns between 20-30 percent BSA receive an AIS score of 3; and second and third degree burns between 30-50 percent BSA receive an AIS score of 4.[31]

To relate the reported body parts affected to BSAs, we use the medical rule of nines – the percent BSA assigned to burns of major extremity parts for anterior and posterior orientations.[32] To simplify the possibilities, we assume both anterior and posterior orientations to a body extremity affected. We assign the arm a BSA of nine percent, and the leg a BSA of 18 percent. When the effect occurs on both legs and arms, we allocate a corresponding BSA of 36 percent and 18 percent. For all other body parts, the BSAs range from 9-18 percent. We understand the non-attribution of body parts reported in the NFIRS data to any one injury. Moreover, thermal burns do not indicate the burn status between first, second, and third-degree burns. Therefore, we assume the clear majority of reported body parts reported reflect thermal burns of second and third degrees. We assume these can be used to approximate the range of BSAs of the 24.1

[29] http://www.traumascores.com/index.php/scores2/16-allgemein/105-104
[30] https://www.webmd.com/lung/smoke_inhalation_treatment_firstaid.htm#4
[31] http://www.traumascores.com/index.php/scores2/16-allgemein/105-104
[32] See https://www.emedicinehealth.com/burn_percentage_in_adults_rule_of_nines/article_em.htm

percent of thermal burns reported. Consequently, the BSA for upper extremities range from 9-18 percent, and receive a burn AIS score of 2. Thermal burns to the lower extremities can account for BSA's of 18-36 percent, which we assume on average best fits an AIS score of 3. Multiple body parts, such as the chest, abdomen, and back, would account for a BSA of 36 percent. Likewise, another scenario involving the legs and abdomen would account for a BSA of 36 percent. While we cannot state which of the possible combinations account for multiple body parts, we find it reasonable to assume this category best fits an AIS score of a 4. For all other body parts, thermal burns do not exceed the 10-20 percent BSA range, and is consistent with an AIS score of 2. Lastly, in our assessment, injuries involving both smoke inhalation and thermal burns do not automatically increase the AIS score. A conservative approach is to assume an AIS score of 2.

We use the preceding information to develop a weighted VSL factor, and the corresponding value of a statistical injury for each fire related injury. We believe that the VSL factor alone does not account for the frequency of sustaining these specific injuries, which impacts consumer valuations of avoiding/preventing an injury. Accordingly, we weigh each VSL factor by the injury occurrence. We assume that each value across injuries is additive to derive the weighted average value of a statistical life. For illustrative purposes, Table 3 describes the methodology concept just discussed. If we assume a $3 million value for a statistical life (VSL), the corresponding value of a statistical injury is $183,000 dollars.

Table 3. Methodological Overview of the Value of a Statistical Injury						
(1) Injury Type	(2) Injury Occurrence	(3) AIS Score	(4) VSL Factor	(5) Weighted VSL Factor (2 x 4) / (∑ of 2)	(6) VSL (millions)	(7) Value of Statistical Injury (6 x 5)
2^{nd}-3^{rd} degree Thermal Burns 10-20% BSA	0.241 x .80 = 0.193	2	0.047	0.011	$3,000,000	$33,000
2^{nd}-3^{rd} degree Thermal Burns 20-30% BSA	0.241 x 0.087 = 0.021	3	0.105	0.003	$3,000,000	$9,000
2^{nd}-3^{rd} degree Thermal Burns 30-50% BSA	0.241 x 0.113 = 0.027	4	0.266	0.009	$3,000,000	$27,000
Both Smoke Inhalation and Thermal Burns	0.131	2	0.047	0.007	$3,000,000	$21,000
Smoke Inhalation	0.409	2	0.047	0.023	$3,000,000	$69,000
Difficulty Breathing	0.062	3	0.105	0.008	$3,000,000	$24,000
Source: NFIRS 2013-2015 Report on Civilian Fire Injuries in Residential Buildings.						

Cost Considerations

To evaluate the real change in marketed resource costs for upholstered manufacturers in implementing the proposed regulation, we consider several important cost factors. These cost factors involve the incremental increase in state enforcement, testing, compliance, financing, fire barrier material, and labor costs. To derive the requisite monetary estimates for each cost input, we utilize data from CPSC (2008), BEARHFTI's fire barrier cost data, and considered estimates from stakeholder interviews. Next, we present the physical dimensions used in our upholstered furniture scenario and follow that with the cost methodology for each cost input.

Upholstered Furniture Dimensions

For this analysis, upholstered furniture includes chairs and sofas. As a fire barrier is located between the cover fabric and the resilient filling material, we need to distinguish whether the whole or only a part of the upholstered furniture would require a fire barrier. A reasonable assumption is a fire barrier will encompass an upholstered furniture's seating cushion, back cushion(s), and the sides of the arm rests. While the entire upholstered furniture item may need a fire barrier under some testing standards, a review of the currently proposed BEARHFTI barrier standard requires only a small-scale composite test of the fire barrier material and resilient filling material to an open flame.[33] Using this standard, we believe the need for encasing the entire upholstered furniture item in a fire barrier is unlikely. Consequently, we adopt the CPSC (2008) estimates of the upholstered furniture dimensions needing a fire barrier that an upholstered chair requires one seating cushion, and two seating cushions for an upholstered sofa. Our assumption being that each cushion requires one linear yard of fire barrier material. Other furniture components, including back cushions, require four linear yards for an upholstered sofa, and two linear yards for an upholstered chair. The total length of fire barrier material assumed is thus six linear yards for an upholstered sofa, and three linear yards for an upholstered chair.

Fire Barrier Material and Labor Costs

BEARHFTI provided us with a list of 19 non-chemically treated fire barriers available in the commercial market. Also provided was a lower and upper bound estimate of the costs per fire barrier type. We use the midpoint value between the average of the lower and upper bound estimates as the baseline estimate for the cost of a fire barrier per linear yard. Importantly, CPSC (2008) states that a common industry practice is the use of a polyester batting between the cover fabric, and resilient filling material for the seating cushion. We agree the inclusion of a fire barrier will likely replace the polyester batting. Accordingly, we adjust the fire barrier cost per linear yard to be less the polyester batting material cost when calculating the fire barrier material

[33] See http://www.bearhfti.ca.gov/industry/proposed_flame_test.pdf

cost for the seating cushion only. This requires the separate calculation of the cost of fire barrier for the other furniture components.

Labor costs account for the expected incremental increase in labor time to incorporate the fire barrier material in the upholstered furniture manufacturing process. We derive this estimate using the incremental increase in minutes per hour for an upholstered sofa and chair, multiplied by the California statewide average hourly rate for furniture finishers.[34] The California Employment Development Department estimates furniture finisher's statewide average hourly wages at $16.14 for first quarter 2017. Additionally, we assume an upholstered sofa will require more time to incorporate fire barrier material. Interviews conducted with multiple representatives of furniture manufactures confirm that on average an upholstered sofa will require 30 min to upholster in an additional fire barrier, in comparison to 15 min for a chair. We use these estimates in our labor cost calculation.[35]

Testing and Compliance Costs

In a BCA application, it is standard to compare the cost of implementing a proposed regulatory standard against the costs of the existing regulatory compliance. Currently, upholstered furniture manufacturers must test and keep compliance records for upholstered furniture meeting the TB 117-2013 smoldering ignition standard. Under the proposed open flame fire barrier standard, upholstered furniture manufacturers would need to perform an additional test and keep separate compliance records. Thus, it is important that we explicitly account for this additional testing and compliance costs required with an open flame standard. Without reliable data that could

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[34] See http://www.labormarketinfo.edd.ca.gov/cgi/dataanalysis/areaselection.asp?tablename=oeswage .

[35] We conducted a phone interview of eight upholstered furniture industry representatives provided by BEARHFTI. The topics discussed ranged from fire barriers, length of time to incorporate a fire barrier, upholstered furniture dimensions, cost estimates, and expected product life cycles. Each industry representative granted their permission to have discussions recorded through written notes, including cost estimates when provided.

account for frequency and cost of testing/record keeping, we inflation adjust the CPSC (2008) estimates to 2017 dollars. We assume these estimates constant across furniture types.

Financing Costs

CPSC (2008) assumes that sellers of furniture use inventory financing as a form of asset-based lending that allows a business to use inventory to obtain a revolving line of credit. If total furniture costs increase, then inventory financing costs also increase. Since material costs of fire barriers alone will increase the cost of upholstered furniture, we incorporate this cost input into the benefit-cost model. We calculate financing costs as the interest rate multiplied by the total incremental increase in cost to upholstered furniture. We use the average between the CPSC (2008) estimate of 10 percent, and our interview estimates of 3.5 and 7.0 percent.

State Enforcement Costs

A task designated to the Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation (BEARHFTI) is the testing of upholstered furniture to ensure regulatory compliance.[36] Currently BEARHFTI ensures upholstered furniture compliance with TB 117-2013 for the residential market. The imposition of a fire barrier performance standard by BEARHFTI will add an additional test requirement and in turn increase the cost. For budget years 2016-2018, BEARHFIT reports that the program expenditure for Home Furnishings and Thermal Insulation will remain constant at about $4.8 million (BEARHFIT, 2017). Without further information on testing and related enforcement expenses, we assume the incremental increase in state enforcement costs fall within the range of an additional 0.5 to 1.5 percent.

Upholstered Furniture Benefit-Cost Model Specification

[36]See http://sbp.senate.ca.gov/sites/sbp.senate.ca.gov/files/BEARHFTI%20Background%20Paper.pdf .

Once we calculate the benefit and costs as described above, BCA requires that aggregation of all them back to a net-present value (NPV) in period zero that equals the discounted stream of benefits, less the discounted stream of costs. BCA requires the aggregation of these over a reasonable time horizon. However, before this aggregation can occur there are a few other considerations. First is whether to conduct the analysis in nominal or real (inflation adjusted) dollars. Since we have no reliable way of predicting the future inflation rate, we present the BCA in constant 2017 dollars using the national CPI index. We chose the year 2017 because we need to begin with a hypothetical year of start for which CPI information available.

A second consideration in the formulation of a BCA is the timing of benefits and costs. The first incursion of a cost determines the starting date (period zero) of a BCA. Technical Bulletin 117-2013 established a one-year grace period to allow adequate time for upholstered furniture businesses to comply with the new regulatory standards (BEARHFTI, n.d.a). Accordingly, we expect that manufactures intending to sell upholstered furniture for residential use in California will quickly comply to develop a supply of furniture that meets the regulatory standard at the end of the grace period. Alternatively, we assume that most consumers are more likely to acquire furniture with fire barriers at the end of the grace period. Consequently, we assume the initial compliance costs occur in period zero (starting year 2017), followed by the initial benefits incurred in period one (the first year that consumer purchase upholstered furniture with required liner).

A third consideration for a BCA is whether the absolute value of future benefits and costs should remain constant throughout the full time of the analysis. As noted earlier, the benefits of this regulation are due in part to a reduction in residential injuries and deaths; but as described earlier, these have exhibited a downward trend since 1985 (USFA, 1997; USFA 2017).

Conceivably this could warrant a downward adjustment in the absolute benefits expected over the time horizon. However, to do this requires an extrapolation beyond the range of existing data. Such an extrapolation assumes that the future reflect a past trend line – an assumption that is often tenuous. Instead, we chose a more conservative approach, project a constant absolute benefit, and cost over the time horizon of the BCA.

Finally, a BCA requires that the calculated benefits and costs share the same unit of analysis. The unit of analysis for benefits is a residential household in California that will have less death, injuries, and property damage if the fire barrier regulation adopted. Costs of the fire barrier regulation relate to upholstered furniture, so we need an assumption regarding the number of upholstered sofas and chairs in a typical California household. We start with a baseline CBA where the typical California household contains two upholstered chairs and one upholstered sofa (we later alter this in a sensitivity analysis). The expected number of households in the state then determines the total cost to all of California in a given year of buying new furniture.[37]

Considering all of this, a formula representation of the NPV calculated from this BCA is:

$$\mathrm{NPV} = \sum_{t=0}^{T=16} \frac{\sum_{i=1}^{\left(\frac{t}{16}\right)*N}(B_i)}{(1+d)^t} - \sum_{t=0}^{T=16} \frac{(C_t)}{(1+d)^t},$$

where;

B_i is the real (inflation adjusted) dollar benefit to a California household (i) in the form of reduced chance of death, injury, and property damage due to adoption of fire barrier standard for upholstered furniture;

C_t is the real (inflation adjusted) dollar cost in state enforcement and manufacturer incurred testing, compliance, financing, and furniture costs for the new upholstered sofa and two new upholstered chairs bought by 1/16 of all California households (assuming a product life cycle of 16 years);

N is the constant average number of California households from 2010 through 2016,

[37] The United States Census Bureau (2016) estimates the average number of California households from 2010 through 2016 at 12,668,236 million.

d is the real (inflation adjusted) discount rate,

t is the period that runs from 0 to 16 (assuming a product life cycle of 16 years).

Based on the distribution of CPSC (2008) reported open flame ignition risk reduction probabilities, we initially assume that the average risk reduction probability achieved by a fire barrier is 0.19. In other words, we expect upholstered furniture with a fire barrier to be 19 percent less likely to ignite from open flame sources, and of the 19 percent of furniture that does not ignite, we assume that no injuries, deaths, or property loss occurs. Accordingly, the percent of households who replace existing furniture not subject to the fire barrier standard is determined by the inverse of the product life cycle. This method, outlined in McNamee *et al.* (2015), assumes households will turnover existing upholstered furniture at the rate equal to the inverse of the product's life cycle. If upholstered furniture chairs and sofas exhibit a product life cycle of 16 years, in any given year one sixteenth (6.25 percent) of all California households will replace their existing upholstered furniture with new upholstered furniture.

For clarity on this assumed process of household replacement of upholstered furniture, we offer an example. In period one, one-sixteenth of all California households replace their upholstered sofa and two chairs and realize a reduction in the likelihood of loss due to an upholstered furniture fire. In period two, the same first one-sixteenth of households realize the same benefit, plus a new one-sixteenth of households begin to do the same. In period three, the same two-sixteenths of households realize the same benefit, plus a new one-sixteenth begins to do the same. This pattern continues, until after 16 years of this, all California households have replaced their pre-furniture barrier furniture and are obtaining the benefits of the fire barrier regulation.

In contrast, the NPV formulation above indicates that the annual cost of implanting this regulation from period zero to 16 is constant. It is equal to the average cost in state enforcement and manufacturer incurred testing, compliance, financing, and furniture costs for the new upholstered sofa and two new upholstered chairs bought by one-sixteenth of all California households. Once this new regulation goes in place, with an upholstered furniture life cycle of 16, the state has set itself up for costs that are equal to implementing it for one sofa and two chairs (as assumed here but later altered in a sensitivity analysis) multiplied by one-sixteenth of all California households.

Chapter 4

Data, Calculations, and Results of the Benefit Cost Analysis of a Regulatory Fire Standard for Upholstered Furniture

Central to this BCA is the magnitude of upholstered furniture fire caused civilian deaths and injuries. The CAL FIRE Incident Reporting System data set, from 2010 through 2016, provides a large sample of 23,506 residential building fires. After restricting the data set to upholstered furniture fires as the first item to ignite from open flame sources, and as the primary contributing material to flame/fire spread, we find (perhaps surprisingly) that an annual average of only 19 residential fires are addressable by the fire barrier performance standard. By year, Table 4 provides the total annual fire losses for civilian deaths, injuries, property and content losses. In contrast to what observed in the national level data for upholstered furniture fires (see NFPA, 2013; Ahrens, 2017), reported fire losses for California appear substantially lower. Since upholstered furniture caused fire losses are the driver of benefits derived from a barrier regulation, the magnitude of them calculated from the California specific data are relatively small. In Tables 5 and 6 below, we summarize the data that serves as the basis for our baseline BCA. At the bottom of Table 5 we list in green the range of expected benefits, in present value terms, from the fire barrier regulation. At the bottom of Table 6 we list in red the range of expected benefits, in present value terms, from the fire barrier regulation. Subtracting the present value of costs from the present value of benefits yields the net present value.

Table 4. Combined Upholstered Furniture Fire Scenarios for Residential Buildings in California					
Year	Incident Count	Property Loss[1]	Content Loss[1]	Civilian Injuries	Civilian Fatalities
2010	20	$1,150,949	$205,647	1	0
2011	31	$1,279,238	$553,167	8	1
2012	17	$468,183	$82,977	1	0
2013	28	$1,345,063	$520,045	0	0
2014	12	$987,017	$302,672	0	0
2015	13	$379,574	$101,570	0	1
2016	13	$510,963	$159,900	2	0
Average	**19**	**$874,427**	**$275,140**	**2**	**0**
[1] All valuations reported are in constant 2017 dollars					

Table 5. Summary of Benefit Data and Calculations used in BCA					
Data Input	Average Whole # Frequency	Average Dollar Value[1]	Lower Bound Dollar Estimate[1]	Upper Bound Dollar Estimate[1]	Source(s)
Value of a Statistical Life		$4,373,404	$3,271,409	$5,841,801	Garbacz (1991)
Value of a Statistical Injury		$266,778	$199,556	$356,350	Garbacz (1991); Department of Transportation (2011); USFA, 2017
Upholstered Furniture Fire Civilian Deaths[2]	0	$0	$0	$0	CAL Fire Incident Reporting System (CAIRS) 2010-2016
Upholstered Furniture Fire Civilian Injuries[2]	2	$533,556	$399,112	$712,700	CAL Fire Incident Reporting System (CAIRS) 2010-2016
Upholstered Furniture Fire Property Loss[2]		$874,427			CAL Fire Incident Reporting System (CAIRS) 2010-2016
Upholstered Furniture Fire Content Loss[2]		$275,140			CAL Fire Incident Reporting System (CAIRS) 2010-2016
Average Societal Cost		$1,683,123	$1,548,679	$1,862,267	
Risk Reduction Probability		0.19	0.19	0.19	
Benefit of Upholstered Furniture Regulation to CA		**$319,793**	**$294,249**	**$353,831**	
[1] All valuations reported are in constant (inflation adjusted) 2017 dollars [2] All residential building fires involving upholstered furniture as the first item to ignite, and as a contributing source. This excludes "other furniture."					

Table 6. Summary of Cost Data and Calculations used in BCA					
Data Input	Average Frequency	Average Dollar Value[1]	Lower Bound Dollar Estimate[1]	Upper Bound Dollar Estimate[1]	Source(s)
Fire Barrier (LY) Cost		$4.92	$4.68	$5.16	BEARHFTI
Fire Barrier (LY) Cost less Polyester Batting		$4.27	$4.03	$4.51	BEARHFTI; CPSC (2008)
Number Seating Cushions per Chair	1	$4.27	$4.03	$4.51	BEARHFTI; CPSC (2008)
LY other Chair parts	2	$9.84	$9.36	$10.32	BEARHFTI; CPSC (2008)
Number Seating Cushions per Sofa	2	$8.54	$8.06	$9.02	BEARHFTI; CPSC (2008)
LY other Sofa parts	4	$19.68	$18.72	$20.64	BEARHFTI; CPSC (2008)
Chair Material Costs		$14.11	$13.39	$14.83	BEARHFTI; CPSC (2008)
Sofa Material Costs		$28.22	$26.78	$29.66	BEARHFTI; CPSC (2008)
Labor Cost per Chair[2]	15min	$4.04			Interviews; CA EDD
Labor Cost per Sofa[2]	30min	$8.07			Interviews; CA EDD
Testing Cost per Chair or Sofa		$0.01			CPSC (2008)
Compliance Cost per Chair or Sofa		$0.13			CPSC (2008)
Inventory Financing Cost per chair[3]		$1.28	$1.23	$1.33	Interviews; CPSC (2008)
Inventory Financing Cost per Sofa[3]		$2.55	$2.45	$2.65	Interviews; CPSC (2008)
Total Manufacturing Cost per Chair		$19.57	$18.80	$20.34	
Total Manufacturing Cost per Sofa		$38.98	$37.44	$40.52	
Chairs per Household	2				
Sofas per Household	1				
Upholstered Furniture Cost per Household		$78.12	$75.04	$81.20	
State Enforcement Estimated Costs		$48,150	$24,075	$72,225	BEARHFTI (2017)
California Households	12,668,235				ACS 2010-2016
Cost of Upholstered Furniture Regulation to CA		**$989,690,668**	**$950,648,429**	**$1,028,732,907**	

[1] All valuations reported are in constant 2017 dollars
[2] Assumes $16.14 hourly wage
[3] Assumes an average 0.07 interest rate

Results

In the first row of Table 7 we offer the range of net present value (NPV) outcomes calculated from this baseline CBA using average value. In addition, in the rows that follow, we vary the value of the benefit and cost input data by the lower and upper bound estimates provide earlier to offer an initial assessment of the impacts of discount rates, values of statistical life and injury, manufacturing costs, and state enforcement costs. The decision criterion relevant for a single policy evaluation is whether the present value of the net benefits over the time horizon exceeds the costs (greater than zero). The range of net present benefits (NPB) for all outcomes presented resulted in $1,721,712 – $2,534,975 million dollars over the 16-year time horizon used. Furthermore, the range of net present costs (NPC) for all outcomes presented resulted in $620,693,130 – $871,921,994 million dollars over the same 16-year time horizon. For all values used in Table 7, the benefits of a proposed fire barrier performance standard for upholstered furniture failed to exceed the costs. Remember that we based this finding upon other variables – most importantly, loses attributed to upholstered furniture held constant – held constant. In the next chapter we offer the results of a sensitivity/switching analysis that indicate the degree of change necessary in these variables to yield a BCA that would yield a positive NPV and hence support the fire barrier performance standard.

Table 7. Summary of Net Present Value Outcomes over a 16 year Time Horizon					
Outcome	Values Used	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0
1[a]	Average Values in Table 5 & 6	$2,291,118	$838,831,008	- $836,539,890	No
2[a]	Lower Bound Values in Table 5 & 6	$2,108,109	$805,740,021	- $803,631,912	No
3[a]	Upper Bound Values in Table 5 & 6	$2,534,975	$871,921,994	- $869,387,020	No
4[b]	Average Values in Table 5 & 6	$1,871,177	$646,184,415	- $644,313,238	No
5[b]	Lower Bound Values in Table 5 & 6	$1,721,712	$620,693,130	- $618,971,419	No
6[b]	Upper Bound Values in Table 5 & 6	$2,070,337	$671,675,699	- $669,605,362	No
[a] Calculations used a 3% discount rate [b] Calculations used a 7% discount rate					

Chapter 5

Robustness Analyses of a Regulatory Fire Standard for Upholstered Furniture

An objective BCA of the efficiency of a regulation investigates the impacts of uncertainty, potential bias in the data, and assumptions used (Fuguitt & Wilcox, 1999). Inherent to the benefit and costs data used here is a level of uncertainty stemming from: (1) limited public data, (2) measurement and sampling error, and (3) the difficulty in predicting future values. In addition, a BCA model can favor positive or negative net present value outcomes, depending on the timing of the benefits and costs over the time horizon.

In terms of our BCA, the most practical method to assess the impacts of uncertainty, and the timing of benefits/costs, is the use of sensitivity analysis on key factors (Fuguitt & Wilcox, 1999). A sensitivity analysis for BCA holds all other variables constant, changes the value of one variable used in the BCA at a time, and checks the impact of this on the net present value of calculated benefits minus costs. If no change occurs in the decision criterion from reasonable changes to variables, the BCA model is robust to a reasonable degree of uncertainty (Fuguitt & Wilcox, 1999).

Due to the number of parameters in the model, we restrict the sensitivity analysis to factors, or variables that have significant impact to the benefits and costs. Additionally, a sensitivity analysis should have a degree of divergence from the baseline used in the primary analysis to provide a meaningful comparison. Given that the benefits of a fire barrier regulation for upholstered furniture occurs through a reduction in fire losses due to it not being in place, we explore alternative levels of fire losses. But we also provide information garnered from other variable changes. All of this is provided next in the form of what happens to NPV when: (1) changing the civilian death and injury occurrences, (2) changing the risk reduction probability,

(3) changing the discount rate, (4) changing the time horizon, and (5) changing the cost of upholstered furniture

Changing the Baseline of Residential Fires Caused by Upholstered Furniture

Historically, fire statistics exhibit a fair degree of uncertainty due to unknown fire characteristics, measurement, and sampling error (USFA, 2012; NFPA, 2013, McNamee & Anderson, 2015; NFPA; 2016). Unknown data represents a sizeable portion of the uncertainty in fire statistics (Thomas & Butry, 2016). A primary cause of this unknown data is reported fire cases with one or more unknown fire characteristics (Hall & Harwood, 1989). More recently NPFA (2013) raised the issue of whether fire departments treat the category other furniture, as either well-defined furniture items that do not fit the other listed categories, or as an unknown category. In the latter case, the relevant impact to the BCA is the potential underestimation of reported fire statistics. The challenge is to what degree the unknown data impacts the civilian caused deaths, injuries, property, and content losses from upholstered furniture ignited by an open flame.

The statistical approach consistently used in fire data to account for unknowns is to allocate proportionally fire characteristics of unknown fires across known fire cases (USFA, 2012b; Thomas & Butry, 2016). In effect, this approach simply scales up the known proportions of fire characteristics equally, but at the cost of assuming the unknown data contains the same share of fire characteristics found in known cases (Hall & Harwood, 1989; USFA, 2012b; Thomas & Butry, 2016). The previous baseline BCA adopted a conservative approach of case-wise deletion of fire cases with reported unknowns on item first to ignite, heat source, and in the case of the second fire scenario, material most contributing to flame or fire spread. Moreover, we treated other furniture at face value. To better account for this inherent uncertainty with case wise deletion and other furniture, we propose an aggressive approach in allocating fire losses coded as other furniture.

Under this alternative baseline, we incorporate all other furniture as the first item to ignite, or as the material contributing most to flame or fire spread, using the same methodology requirements for both fire scenarios. There are two reasons for this approach. The first is proportionally allocating unknown data in categories of item first to ignite, or heat source, would only produce minor changes in the fire data (Hall & Harwood, 1989). As noted in Table 8, this approach significantly increases the upholstered furniture caused fire losses considered addressable by the fire standard. Table 9 reports a new summary of net present value outcomes, including both lower and upper bound values. The range of net present value outcomes for all scenarios still reflect negative net present values of $609,622,622 – $835,093,049 million dollars over the 16-year time horizon.

Table 8. Combined Upholstered Furniture Fire Scenarios for Residential Buildings in California using Other Furniture Category					
Year	Incident Count	Property Loss[1]	Content Loss[1]	Civilian Injuries	Civilian Fatalities
2010	117	$5,682,574	$1,409,740	8	5
2011	110	$3,644,189	$1,242,905	13	3
2012	85	$4,875,448	$2,543,939	9	2
2013	97	$4,205,388	$1,113,966	14	0
2014	69	$3,801,951	$1,097,082	3	0
2015	64	$1,856,314	$548,547	0	2
2016	77	$4,232,166	$857,413	8	2
Average	**88**	**$4,042,576**	**$1,259,085**	**8**	**2**
[1] All valuations reported are in constant 2017 dollars					

Table 9. Summary of Net Present Value Outcomes of Alternative Fire Loss Baseline over a 16 year Time Horizon					
Outcome	Values Used	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0
1[a]	Average Benefit and Cost values	$22,028,374	$838,831,008	- $816,802,633	No
2[a]	Lower Bound Benefit and Cost Values	$18,296,199	$805,740,021	- $787,443,822	No
3[a]	Upper Bound Benefit and Cost Values	$27,001,453	$871,921,994	- $844,920,541	No
4[b]	Average Benefit and Cost values	$17,990,773	$646,184,415	- $628,193,642	No
5[b]	Lower Bound Benefit and Cost Values	$14,942,672	$620,693,130	- $605,750,459	No
6[b]	Upper Bound Benefit and Cost Values	$22,052,332	$671,675,699	- $649,623,368	No
[a] Calculations used a 3% discount rate [b] Calculations used a 7% discount rate					

Changing the Civilian Death and Injury Occurrences

Two crucial factors to determining the overall benefits is the number of annual civilian deaths and injuries. Given the level of uncertainty in the fire data, we believe it reasonable to consider significant shocks to the number of civilian deaths and injuries to evaluate its relative impact on net present value outcomes. Table 10 provides a range of sensitivity outcomes from the alternative fire loss baseline, with the necessary model assumptions noted in Appendix. The exception is outcomes five and six where we provide an evaluation of the combined effect of worst case scenario for each of the injury, death, property, and content loss that occurred during 2010 through 2016. Even under these large fire loss scenarios, the range of net present value outcomes only vary between negative $570,968,315 and $815,350,048 million dollars over a 16-year time horizon. **As important points of reference, holding all other variables constant, only at 132 to 140 residential home deaths, or 2,110 to 2241 residential home deaths, does the CBA yield a net present value outcome greater than zero. If all four fire loss categories increase proportionally from worst case values, only at an increase greater than 1000 percent does the calculated net present value rise to greater than zero. Given this required magnitude of fire losses, we can state with high certainty that the expected benefits of a fire barrier do not exceed its expected costs.**

Table 10. Sensitivity Analysis of Civilian Deaths and Injuries over a 16-year Time Horizon						
	Value(s) Used in Sensitivity	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0	Input Change Needed for NPV > 0
1[a]	50 percent increase in Average number of Civilian Deaths	$27,981,585	$838,831,008	-$810,849,423	No	140 Deaths
2[a]	50 percent increase in Average number of Civilian Injuries	$23,480,960	$838,831,008	-$815,350,048	No	2241 Injuries
3[a]	100 percent increase in Average number of Civilian Deaths	$33,934,796	$838,831,008	-$804,896,212	No	140 Deaths
4[a]	100 percent increase in Average number of Civilian Injuries	$24,933,545	$838,831,008	-$813,897,463	No	2241 Injuries
5[b]	50 percent Increase in Worst Case Scenarios for All Upholstered Furniture Fire loss categories	$58,843,095	$646,184,415	-$587,341,320	No	Greater than 1000 percent increase to all fire loss categories
6[b]	100 percent Increase in Worst Case Scenarios for All Upholstered Furniture Fire loss categories	$75,216,099	$646,184,415	-$570,968,315	No	Greater than 1000 percent increase to all fire loss categories

[a] Calculations used a 3% discount rate
[b] Calculations used a 7% discount rate

Changing the Risk Reduction Probability

Throughout this CBA we assumed an average risk reduction probability of 19 percent based on the ranges provided by the CPSC. Given that we based this value on CPSC's judgement, it is reasonable to assume a degree of uncertainty with the risk reduction probability. Accordingly, we examine the impacts of assuming a 51 percent risk reduction probability consistent with upholstered furniture deemed severely ignition prone to an open flame, and a 25 percent risk reduction probability for moderately ignition prone upholstered furniture (see CPCSC, 2008). Table 11 provides a range of sensitivity outcomes of both the risk reduction probabilities, and with worst case fire loss scenarios not held constant. We further provide necessary model assumptions in Appendix. The net present value (NPV) outcomes for all sensitivity scenarios are negative with a range of -$444,288,569 to -$809,846,305 over a 16-year time horizon. To obtain a net present value outcome would require the impossible probability value of greater than one. This sensitivity analysis provides evidence that the original assumption of a19 percent risk reduction of fire barriers exerts a decisive impact to our determination of it failing a BCA.

Table 11. Sensitivity of Assumed Fire Barrier Risk Reductions and Fire Losses over a 16-year Time Horizon

	Value(s) Used in Sensitivity	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0	Input Needed for NPV > 0
1[a]	P(r) of .51 for Upholstered Furniture	$59,128,795	$838,831,008	-$779,702,213	No	P(r) exceeds 1
2[a]	P(r) of .25 for Upholstered Furniture	$28,984,703	$838,831,008	-$809,846,305	No	P(r) exceeds 1
3[b]	P(r) of .51 for Upholstered Furniture	$48,291,023	$646,184,415	-$597,893,392	No	P(r) exceeds 1
4[b]	P(r) of .25 for Upholstered Furniture	$23,672,070	$646,184,415	-$622,512,345	No	P(r) exceeds 1
5[b]	P(r) of .51 and 100 percent Increase in Worst Case Scenarios for all Upholstered Furniture Fire loss categories	$201,895,846	$646,184,415	-$444,288,569	No	P(r) exceeds 1
5[b]	P(r) of .25 and 100 percent Increase in Worst Case Scenarios for all Upholstered Furniture Fire loss categories	$98,968,552	$646,184,415	-$547,215,863	No	P(r) exceeds 1

[a] Calculations used a 3% discount rate
[b] Calculations used a 7% discount rate

Changing the Discount Rate

The costs of a fire barrier in upholstered furniture occur at the time of the manufacture, but the realization of benefits in fire reduction due to barrier occur each year that the product exists. A consequence is that present value of the benefits of a fire barrier decrease with an increase in the discount rate, while the proportional decreases in the present value of costs also accelerate. A review of the literature indicates some support for the use of as high a10 percent real discount rate (Dardis, 1980b; McNamee *et al.*, 2015). Justification for the use of a high real (adjusted for inflation) discount rate comes from the belief that Californians are very present orientated and are willing to trade off a good occurrence in the future, for far less of the same good occurrence immediately.

In Table 12 we report upon a sensitivity analysis of both the discount rate, and with worst case fire loss scenarios not held constant. Further details on necessary model assumptions are in Appendix. The net present value (NPV) outcomes for all sensitivity scenarios are again negative and range from -$480,106,005 to -$530,084,045 over a 16-year time horizon. Furthermore, even after accounting for large fire losses do we ever find a positive NPV.

Table 12. Sensitivity of Discount Rate and Fire Losses over a 16-year Time Horizon

	Value(s) Used in Sensitivity	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0	Input Needed for NPV > 0
1	10% Discount Rate	$15,712,337	$545,796,381	-$530,084,045	No	Discount rate > 100%
2	10% Discount Rate and 100 percent Increase in Worst Case Scenarios for all Upholstered Furniture Fire loss categories	$65,690,377	$545,796,381	-$480,106,005	No	Discount rate > 100%

Changing the Time Horizon

An alternative method in evaluating the impacts of the timing of benefits and costs is to alter the assumed time horizon. In this BCA the useful life of upholstered furniture determines the time horizon. A longer time horizon also increases the discounting effect for benefits and costs realized in later years. Table 13 provides a sensitivity analysis of both the time horizon, and with worst case fire loss scenarios not held constant. The net present value (NPV) outcomes for all sensitivity scenarios are again negative and range between -$310,993,795 to -$709,441,651 million dollars over a 16-year time horizon. Here, we do not calculate input changes beyond 32 years because likely policy or technology changes will occur, and invalidate the results of unrealistically long-time horizons. Subsequently, all four scenarios demonstrate the net present value outcome is robust to substantial changes in the time horizon, and in combination with large increases in fire losses.

Table 13. Sensitivity of the Time Horizon and Fire Losses

	Value(s) Used in Sensitivity	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0
1[a]	24-year Time Horizon	$30,168,293	$739,609,944	-$709,441,651	No
2[a]	32-year Time Horizon	$37,188,748	$661,508,177	-$624,319,428	No
3[b]	24-year Time Horizon and 100 percent Increase in Worst Case Scenarios for all Upholstered Furniture Fire loss categories	$95,880,491	$514,199,312	-$418,318,822	No
4[b]	32-year Time Horizon and 100 percent Increase in Worst Case Scenarios for all Upholstered Furniture Fire loss categories	$111,064,594	$422,058,389	-$310,993,795	No

[a] Calculations used a 3% discount rate
[b] Calculations used a 7% discount rate

Changing the Cost of Upholstered Furniture

When examining the findings of BCA conducted after a regulation put in place, it has often noted that the estimation of future costs is often significantly greater when compared to the costs that occurred after the regulation in place. Kopits *et al.* (2014) note several factors that impact the accuracy of *ex ante* cost estimates. Of those described, two are particularly relevant to the BCA performed her. First industry representatives generally have better information about the cost of complying with regulatory standards, and this asymmetric information incentivizes giving plausible, but unlikely his cost estimates to analysts. However, it is also important to consider that regulatory agencies seeking to pass a standard may have the incentive to underestimate the true cost of the regulation to consumers in higher prices and/or firms in lower profits. A point often presented by industry representatives of increasingly burdensome regulations.

From our perspective of independent analysts, it is not unreasonable to suggest that our initial range of cost estimates is subject to a degree of uncertainty. So consistent with our desire to generate as objective an analysis as possible, we next examine two cost scenarios: (1) an underestimation of the average costs of upholstered furniture per household by 50 percent (2) an overestimation of the average costs of upholstered furniture by 50 percent. This provides a more complete examination of the impact of costs to the previously reported lowest negative net present value outcomes from either perspective of uncertainty. Table 14 provides a sensitivity analysis of the changing costs of upholstered furniture per household, paired with the lowest negative NPV scenarios. The net present value (NPV) outcomes for all sensitivity scenarios are negative values from -$99,974,868 to -$894,044,804. To obtain net present value outcomes greater than zero, the costs per household would need to be as low as $9.08 to $24.40. These results offer the distinct conclusion that the combination of benefits and cost circumstances required to obtain net present values greater than zero are unlikely to occur. Regardless of the inherent uncertainty in either benefit or cost data, we demonstrate any reasonable variation in benefits and costs fail to produce a positive net present value outcome.

Table 14. Sensitivity Analysis of the Cost of Upholstered Furniture and Lowest Negative NPV Scenarios

	Value(s) Used in Sensitivity	NPB (in 2017$)	NPC (in 2017$)	NPV (in 2017$)	Decision Criteria: NPV > 0	Input Needed for NPV > 0
1[a]	50 percent increase in Upholstered Furniture Cost per Household	$75,216,099	$969,260,903	-$894,044,804	No	Per Household cost of $9.08
2[b]	50 percent decrease in Upholstered Furniture Cost per Household	$75,216,099	$323,107,926	-$247,891,827	No	Per Household cost of $9.08
3[c]	50 percent increase in Upholstered Furniture Cost per Household	$201,895,846	$969,260,903	-$767,365,057	No	Per Household cost of $24.40
4[d]	50 percent decrease in Upholstered Furniture Cost per Household	$201,895,846	$323,107,926	-$121,212,080	No	Per Household cost of $24.40
5[e]	50 percent increase in Upholstered Furniture Cost per Household	$65,690,377	$818,681,295	-$752,990,919	No	Per Household cost of $9.39
6[f]	50 percent decrease in Upholstered Furniture Cost per Household	$65,690,377	$272,911,468	-$207,221,091	No	Per Household cost of $9.39
7[g]	50 percent increase in Upholstered Furniture Cost per Household	$111,064,594	$633,077,317	-$522,012,723	No	Per Household cost of $20.55
8[h]	50 percent decrease in Upholstered Furniture Cost per Household	$111,064,594	$211,039,461	-$99,974,868	No	Per Household cost of $20.55

[a & b] Uses 100 percent increase in worst case scenarios for all upholstered furniture fire loss categories, 16 year time horizon, P(r) .19, and a 7% discount rate.
[c & d] Uses 100 percent increase in worst case scenarios for all upholstered furniture fire loss categories, 16 year time horizon, P(r) .51, and a 7% discount rate.
[e & f] Uses 100 percent increase in worst case scenarios for all upholstered furniture fire loss categories, 16 year time horizon, P(r) .19, and a 10% discount rate.
[g & h] Uses 100 percent increase in worst case scenarios for all upholstered furniture fire loss categories, 32 year time horizon, P(r) .19, and a 7% discount rate.

Appendix

Table 5. Summary of Alternative Fire Loss Baseline and Calculations used in Sensitivity Analyses				
Data Input	Average Frequency	Average Value[1]	Worst Case Scenario Frequency	Valuations for Worst Case Scenario[1]
Value of a Statistical Life		$4,373,404		$4,373,404
Value of a Statistical Injury		$266,778		$266,778
Upholstered Furniture Fire Civilian Deaths	2	$8,746,808	5	$21,867,020
Upholstered Furniture Fire Civilian Injuries	8	$2,134,224	14	$3,734,892
Upholstered Furniture Fire Property Loss		$4,042,576		$5,682,574
Upholstered Furniture Fire Content Loss		$1,259,085		$2,543,939
Risk Reduction Probability		0.19		
[1] All valuations reported are in constant 2017 dollars				

Table 6. Summary of Baseline Cost Data and Calculations used in the Sensitivity Analyses		
Data Input	Average Frequency	Average Value[1]
Fire Barrier (LY) Cost		$4.92
Fire Barrier (LY) Cost less Polyester Batting		$4.27
Number Seating Cushions per Chair	1	$4.27
LY other Chair parts	2	$9.84
Number Seating Cushions per Sofa	2	$8.54
LY other Sofa parts	4	$19.68
Chair Material Costs		$14.11
Sofa Material Costs		$28.22
Labor Cost per Chair[2]	15min	$4.04
Labor Cost per Sofa[2]	30min	$8.07
Testing Cost per Chair or Sofa		$0.01
Compliance Cost per Chair or Sofa		$0.13
Inventory Financing Cost per chair[3]		$1.28
Inventory Financing Cost per Sofa[3]		$2.55
Total Manufacturing Cost per Chair		$19.57
Total Manufacturing Cost per Sofa		$38.98
Chairs per Household	2	
Sofas per Household	1	
Upholstered Furniture Cost per Household		$78.12
State Enforcement Estimated Costs		$48,150
California Households	12,668,235	
[1] All valuations reported are in constant 2017 dollars [2] Assumes $16.14 hourly wage [3] Assumes $16.14 hourly wage [4] Assumes an average 0.07 interest rate		

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