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Weighting of Firefighting Turnout Gear Risk Factors According to Expert Opinion

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Abstract: Firefighters in Taiwan often wear expired protective clothing, which raises concerns regarding their safety. Extending the service life of fire protective clothing can improve firefighter safety and ensure environmental sustainability. In this study, an analytic hierarchy process was used to understand which risk factors should be prioritized in the design of firefighting turnout gear. We surveyed 30 experts in the field of firefighting and safety management on the importance of various risk factors related to turnout gear. A risk level of 70% was taken as the threshold of tolerable risk. The rankings of the weighted risk factors demonstrate that eliminating 12 of the 28 risk factors will result in 73% safety. These 12 factors are, in order of maximum risk, insufficient flame resistance, insufficient heat resistance, putting on the suit components in the wrong order, insufficient resistance to tears and punctures, poor agility, heavy overall weight, insufficient water resistance, lack of flame-retardant fibers, high levels of toxicity, insufficient internal circulation, no air filtration device, and poor air permeability. Consideration of these factors in the design of fire protective clothing can extend service life, help achieve sustainable development goals, and ensure firefighters' safety.

Keywords: firefighting turnout gear; risk factors; analytic hierarchy process; weighting analysis; sustainability

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1. Introduction

In Taiwan, firefighting turnout gear exceeding its expiry seems to be the norm, and relevant news involving different municipal fire departments are reported every year as a result, but the issue persists. Taiwan currently follows both the US NFPA and the EU EN469 specifications on turnout gear. Each municipality is allowed to purchase turnout gear at their discretion as long as the gear is compliant with American, European, or Japanese standards. As a result, the purchased gear may not come with the original manufacturers' specifications or certifications. Some sets of gear do not include user manuals. The same set of turnout gear is also often shared by multiple firefighters [1].

By the end of March 2015, the Taipei City Fire Department had 1243 firefighters, each of whom must be equipped with a set of turnout gear (bunker gear), including disaster relief personnel (those who enter the fire site), and emergency medical services personnel (those who set up outside the fire site). The Taipei City Fire Department currently has 1410 sets of turnout gear, but only 349 sets have expiries within the next three years and are compliant with the Executive Yuan's (Taiwanese executive branch) regulations on asset registration; the remaining 1061 sets of gear are expired [2]. According to a 2021 audit report [3], half of the Taichung City Fire Department's equipment is expired: 1367 out of 1434 safety alerts (95.33%), 1611 out of 2879 sets of turnout gear (55.96%), 917 out of 1395 oxygen masks (65.73%), 646 out of 1137 air cylinders (56.82%), and 51 out of 67 thermal imagers (76.12%). Taichung City's improvement targets are to allocate one suit to each firefighter every three years and to replace the suits every six years; in other words, each person would be equipped with two suits [4]. Expired sets of turnout gear can exhibit (1) damaged reflective strips, resulting in poor visibility in fires and the firefighters being unable to see each other; (2) loosened suspenders, causing the trousers to fall and trip the firefighter; (3) damage to the outer shell that affects the thermal insulation of the suit, affecting rescue missions as the damaged areas increase in size over time; and (4) loss of waterproofing, making firefighters liable to be scalded by water heated while extinguishing fires. Increasing the strength of the fabric in all aspects and the service life of fire protective clothing is an effective solution that resonates with the 17 sustainable development goals (SDGs) [5,6] proposed at the United Nationals Sustainable Development Summit. Product lifespan is a major problem in sustainability, and a product's sustainability strongly affects decision-making during new product development. [7]. Therefore, this study performed analytical hierarchy process (AHP) expert questionnaire analysis [8] to identify key factors for designing fire protective clothing and the components that should be improved in terms of materials to increase service life and achieve the SDGs.

2. Literature Review

2.1. Research on Fire Protective Clothing

Lu et al. [9] noted that overdesigned turnout gear can cause more thermal stress for the wearer; therefore, understanding the fires that firefighters encounter is crucial to preventing overdesign. Heat mainly dissipates from the body through evaporation [10,11]. Reducing the weight of turnout gear can substantially reduce metabolic rates for firefighters and may enable heat stress to be controlled.

Every country has its own regulations on firefighting turnout gear. Turnout gear currently used in Taiwan is compliant with the U.S. National Fire Protection Association (NFPA) and European Norm (EN) specifications. Roguski et al. [12] compared the U.S., Russian, and European (mostly Polish) regulations on turnout gear standards and testing methods, as outlined in the US NFPA 1971, НПБ162-02, and EN 469 regulations.

In Taiwan, there is a problem that firefighters wear expired fire protection equipment on duty, where the capital of Taipei has 1243 firefighters and only 349 un-expired sets of turnout gear [13]. Taiwan's regulations require that firefighter clothing, hats, and shoes must be replaced every 3 years, masks every 4 years, and air cylinders every 10 years. However, due to budget shortages, expired equipment remains in use.

Lu et al. [14] determined that radiant heat affects the service life of turnout gear. The tensile strength of turnout gear decreases as the frequency of exposure to radiant heat increases, and for the same duration of cumulative exposure, longer durations of exposure lead to lower tensile strength. Furthermore, improperly maintained turnout gear will not reach the expected service life. Effective ways to protect turnout gear include line drying, which can slow down the speed of water removal and reduce damage to the suit, and tumble dryers, which use high spinning speeds to remove residual moisture and reduce dryer use times [15].

Lah et al. [16] discovered a new shape-memory nitinol knitted fabric that can transform from a two-dimensional state to a three-dimensional state at temperatures of 75 °C (or higher). This fabric can be used to increase air gaps in protective clothing to enhance thermal protection and prevent burn injuries. Phelps et al. [17] added phase-change material (PCM) and air gaps close to the outer shell of turnout gear to lower the possibility of skin burns. In their study, a MgCl2 center dot 6H(2)rO with an overall thickness of 0.17 mm gave the optimal improvement in the time until thermal skin damage occurred.

Fonseca et al. [18] determined optimal PCM masses, the cooling time of PCM suits, and the protection time against second- and third-degree burns. They also calculated the thermal protective performance of turnout gear at each firefighting stage (triaging the fire,

fire exposure, post fire exposure, and resting phases) based on heat flow and wind speed. Experiments on the thermal protective performance of turnout gear after absorbing water in firefighting scenarios determined that given the coupling effects of the humidity–heat, a certain level of water content can increase the thermal protective performance of turnout gear, but if the water content of the suit approaches levels of immersion, excessive thermal conductivity will lower the thermal protective performance [19].

Graphene oxide (rGO) reduced using L-ascorbic acid demonstrated higher performance in flame resistance and durability, and silk fabric deposited with 19.5 wt% rGO can be used in the manufacturing of refractory conductors. Silk fabric deposited with 3.9 wt% rGO can be used in the manufacturing of signal transmission sensors to increase the technological functionality and flexibility of firefighting gear [20].

Working under stressful conditions for long periods may lead to the development of post-traumatic stress disorder (PTSD) among firefighters. Witt et al. [21] surveyed 147 firefighters and found that one-third of the respondents suffered from symptoms of PTSD, and PTSD was especially prevalent among older firefighters. Instances of increased stress leading to cardiac arrest in firefighters were also reported. A health survey of petrochemical firefighters determined that the most abnormal value in firefighters' blood was cholesterol, which may be due to limited physical activity and chemical exposure [22]. Compared with typical company employees, firefighters are at a higher risk of work-related physical injuries. An investigation of firefighters' musculoskeletal injuries found that the main areas of injury were the lower limbs and back; injuries to the hands were mainly sprains and strains, usually caused by slipping, tripping, or falling [23].

Abrard et al. [24], studying the physiological responses of firefighters after a fire, determined that exposure to high ambient temperatures for 30 min led to an increased forehead temperature of 0.5 °C, a mean water body loss of 639 mL, and a mean heart rate increase of 7.5 bpm. Their study indicated that after 30 min of exposure to high ambient temperatures, heat stress had little effect on firefighters. However, stress increases exponentially over time; therefore, a longer period of rest is necessary before re-engaging in a second firefighting task.

Turnout gear affects firefighters' mobility, which can increase the risk of injury. According to Orr et al. [25], common areas of discomfort were the knees and thighs. Increasing mobility around the lower limbs may help reduce firefighter injuries and discomfort.

2.2. Research on Sustainable Apparel

The depletion of global natural resources is a major environmental and social problem [26]. Human beings are standing at a key crossroads and face drastic changes to the global climate, the gradual depletion of natural resources, a decrease in biodiversity, and the frequent emergence of diseases. In 2015, the United Nations Sustainable Development Summit released the 17 SDGs in "Transforming Our World: the 2030 Agenda for Sustainable Development" to bolster efforts to protect the earth and human society before 2030 and advance toward sustainable development [5,6].

According to The Business of Fashion [27], 25% of all chemicals produced are used for textile production; the fashion industry is the world's second most polluting industry, after the oil industry, and approximately 10% of the world's global carbon emissions result from the apparel and textile industry. From the perspective of clothing design, the intention behind sustainable design is to "eliminate negative environmental impacts completely through skillful, thoughtful design" [7].

Jiang et al. [28] identified three aspects of sustainable clothing design: (1) reducing and optimizing the use of materials, (2) conveying ideas through emotional design methods, and (3) increasing the service life of clothing; the third aspect was highlighted as the easiest and fastest to implement.

With environmental protection gaining increasing attention [29], manufacturers have begun to produce and market sustainable clothing [30]. Sustainable clothing is "clothing that integrates multiple aspects of social and environmental sustainability, such as fair trade, friendly manufacturing, and organic fabrics" [31]. Rausch and Kopplin [32] defined sustainable clothing as clothing made from environmentally friendly, recyclable, or biodegradable fibers and produced under reasonable working conditions.

Increasing the lifespan of clothing is critical to reducing its carbon footprint. Academics have noted that textiles made from sustainable materials have a smaller effect on the environment [33]. Sarwar et al. [34] remarked that the use of numerous hazardous chemicals in the manufacture of textiles is cause for concern; thus, sustainable garments must be manufactured with fewer toxic chemicals. Although the production, distribution, and disposal of clothing inevitably affect the environment, according to Goworek et al. [7], increasing the durability of clothing through design, maintenance, and reuse is an effective method of reducing environmental damage.

Numerous aspects of the clothing industry can be improved to ensure sustainability. The optimization of a product's socioeconomic and environmental effects is becoming increasingly crucial for customers and regulating institutions. However, a gap between sustainable attitudes and behaviors remains [35]. Jacobs et al. [36] explored the attitude–behavior gap. They observed that egoistic and hedonic values and a preference for durable clothing discourage the purchase of sustainable clothing. A study by Rausch and Kopplin [35] indicated that attitudes toward sustainable clothing had the strongest effect on purchase intention and that this relation was negatively influenced by consumers' concerns regarding greenwashing.

3. Research Method

This study reviewed the literature and used the modified Delphi method [37] and an AHP expert questionnaire [38]. During the literature review, we explored research on turnout gear, identified factors affecting its design, and applied the modified Delphi method to determine several dimensions and factors related to risk in the design of turnout gear. An expert group survey was performed to collect opinions regarding these factors, and a consensus was reached, which was then used to develop an AHP expert questionnaire. The weights of the questionnaire were subsequently analyzed to determine the priorities of risk assessment indicators in the design of turnout gear.

3.1. AHP Expert Survey

The analytic hierarchy process was developed by Thomas L. Saaty in 1971 and is mainly used in decision-making problems in uncertain situations with multiple sets of criteria [38]. AHP systemizes complex problems, providing hierarchical deconstruction from different levels and using quantitative calculations to determine and comprehensively evaluate the context [39,40]. Five experts with more than 15 years of work experience each (two senior firefighters, one college professor in fire safety, one functional clothing designer, and one college professor in textiles and clothing) completed the preliminary questionnaire and analyzed the constructs (first layer) and risk assessment indicators (second layer; Figure 1), thereby ensuring the reliability and validity of this study.

To evaluate the importance of the risk factors and in accordance with AHP [41,42], 30 experts, including professional designers of turnout gear, members of the National Fire Agency and local fire departments, members of the National Police Agency, and scholars of safety management, were asked to fill out a questionnaire (Supplementary Materials); 23 valid responses were collected. Using AHP, 28 risk factors were ordered from high to low risk based on their weight values. Risk factors with cumulative weights of 70% were selected as priority items to be addressed in the design of turnout gear (12 items).

3.2. Risk Assessment Indicators

Turnout gear is necessary equipment for ensuring the safety of frontline firefighters. Its function is mainly to prevent life-threatening instances in a fire scenario. Determining how turnout gear can provide effective fire protection, as well as mobility and comfort to the needs of frontline firefighters, is imperative.

Turnout gear consists of multiple layers of fabric: an outer layer, waterproof and breathable layer, heat insulation layer, and comfort layer. Turnout gear protects firefighters' upper and lower torsos, necks, arms, and legs but not their heads, hands, or feet. Turnout gear generally offers high coverage, enclosure, and convenience. Turnout gear must provide permanent fire retardancy, high tenacity, and high-wear resistance, and different materials are used for different purposes.

Turnout gear is made with fire-retardant thread. To ensure its firmness, turnout gear is also made using double-needle-felled seams. The front of turnout gear is closed using a zipper and hood-and-loop fastener, and personal belongings can be placed inside two internal pockets. In addition, turnout gear has seamless shoulders, inner rib knit cuffs, a standing collar, drawstring leg holes, adjustable bib overalls with reinforced knee patches (for wear resistance), reflective stripes, and sleeves that enable the maximum range of arm motion.

After interviewing five firefighting experts (a representative from the Taiwan National Fire Agency, a firefighter, a technological materials researcher, a scholar in fire prevention, and a scholar in textiles and clothing), we decided to divide this study into two levels. The first level focused on suit protection, comfort, materials, cutting, and technology. The second level involved a discussion of the safety of turnout gear designs based on risk decision factors proposed by the panel of experts (Figure 1).

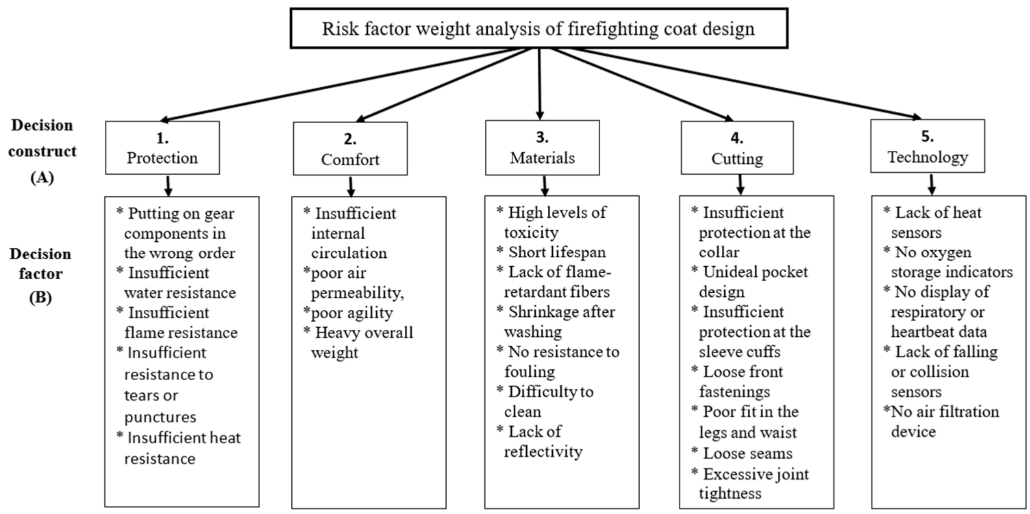

Figure 1. Risk assessment indicators.

Risk decision factors in the design of turnout gear were discussed according to the five major level-one domains: protection, comfort, materials, cutting, and technology. The level-two risk factors were as follows:

1. Protection: putting on the gear components in the wrong order, insufficient water resistance, insufficient flame resistance, insufficient resistance to tears or punctures, and insufficient heat resistance;
2. Comfort: insufficient internal circulation, poor air permeability, poor agility, heavy overall weight;
3. Materials: high levels of toxicity, short lifespan, lack of flame-resistant fibers, shrinkage after washing, no resistance to fouling (oil stains, carbon particles, etc.), difficulty to clean, lack of reflectivity;
4. Cutting: insufficient protection at the collar, unideal pocket design, insufficient protection at sleeve cuffs, loose front fastenings, poor fit in trousers and waist, loose seams, and excessive tightness in joints;
5. Technology: lack of heat sensors, no indicators of oxygen storage data, no display of respiratory or heartbeat data, lack of falling or collision sensors, no air filtration devices.

4. Results and Discussion

4.1. AHP Survey Results and Discussion

Per the Taiwanese Handbook for Risk Management and Crisis Handling of the Executive Yuan and Affiliated Agencies [43], published in September 2020, a tolerable risk of 80–100% is low and therefore negligible, a tolerable risk of 60–79% is moderate and therefore acceptable, and a tolerable risk of 59% or less is high, unacceptable, and requires improvement (Table 1).

Table 1. Levels of risk tolerance.

Risk Level	Tolerable Risk Range	Level of Tolerance
High	59% or less	Requires improvement
Moderate	60–79%	Acceptable
Low	80–100%	Negligible

Handbook for Risk Management and Crisis Handling of the Executive Yuan and Affiliated Agencies, published September 2020 [43].

4.1.1. Risk Decision Constructs

The analysis of the decision constructs based on the survey results is presented in Table 2. The decision constructs were protection, comfort, materials, cutting, and technology. Among these five constructs, protection demonstrated the greatest weight value; the others, in order, were material, comfort, technology, and cutting. Protection was the foremost domain in decision-making because protection is the primary function of turnout gear.

Table 2. Risk decision factors by weight.

Decision Construct	Weight Values	Rank
Protection	0.422366	1
Comfort	0.178665	3
Material	0.186749	2
Cutting	0.073938	5
Technology	0.138282	4
	Sum of weight values = 1	

4.1.2. Analysis of Risk Decision Factors

The analysis of the risk decision factors involved five factors relating to protection, four factors relating to comfort, seven factors relating to material, seven factors relating to cutting, and five factors relating to technology.

1. Risk decision factors relating to protection

Insufficient flame resistance (0.264305) was the factor with the highest risk among all factors relating to protection and ranked first among all risk factors. Insufficient heat resistance (0.259234) was the protection factor with the second highest risk and ranked second among all factors. Putting on gear components in the wrong order (0.200990) was ranked third among all risk factors (Table 3). These results indicate that within the protection domain, most experts consider flame resistance to be the number one priority. In fact, the top four decision risk factors by weight were all attributed to the protection construct. The factor with the lowest ranking among the protection factors, insufficient water resistance (0.119449), was ranked seventh among all decision risk factors by weight. This demonstrates that protection should be prioritized among all the decision constructs in the design of turnout gear.

Table 3. Risk decision factors relating to protection.

Decision Construct (A)	Decision Factor (B)	Weight (A × B)	Rank
Protection (0.422366)	Putting on gear components in the wrong order (0.200990)	0.08489	3
	Insufficient water resistance (0.119449)	0.05045	7
	Insufficient flame resistance (0.264305)	0.11163	1
	Insufficient resistance to tears or punctures (0.156022)	0.06590	4
	Insufficient heat resistance (0.259234)	0.10949	2
	Total weight sum = 1		

2. Risk decision factors relating to comfort

Poor agility (0.288961) was the factor with the highest risk among all factors relating to comfort and ranked fifth among all risk factors. Heavy overall weight (0.282635) was the comfort factor with the second highest risk and ranked sixth among all risk factors. Insufficient internal circulation (0.226364) ranked tenth among all risk factors (Table 4). These results demonstrate that most experts considered agility to have priority within the comfort domain. These results are also consistent with the description in the previous section of the research team experiencing for themselves the clumsiness of wearing turnout gear. Restricted agility while wearing turnout gear might lead to unfavorable outcomes.

Table 4. Risk decision factors relating to comfort.

Decision Construct (A)	Decision Factor (B)	Weight (A × B)	Rank
Comfort (0.178665)	Insufficient internal circulation (0.226364)	0.04044	10
	Poor air permeability (0.202039)	0.03610	12
	Poor agility (0.288961)	0.05163	5
	Heavy overall weight (0.282635)	0.05050	6
	Total weight sum = 1		

3. Risk decision factors relating to material

Lack of flame-retardant fibers (0.264281) was the factor with the highest risk among all factors relating to material and was ranked eighth among all risk factors. High levels of toxicity (0.243913) were the material factor with the second highest risk and ranked ninth among all risk factors. Lack of reflectivity (0.134084) ranked fifteenth among all risk factors (Table 5). These results demonstrate that most experts consider the lack of flame-retardant fibers to have priority in the material domain. If a material lacks flame-retardant fibers, the turnout gear will exhibit no protective function. Thus, replacing flame-retardant fibers in old or damaged turnout gear is crucial.

4. Risk decision factors relating to clothing cutting

Insufficient protection at the collar (0.199514) was the factor with the highest risk among all clothing cutting domain factors and ranked 20th among all risk factors. Loose front fastenings (0.168525) were the clothing cutting factor with the second highest risk and ranked 23rd among all risk factors. Loose seams (0.162610) were ranked 24th among all risk factors (Table 6). These results indicate that most experts considered protection at the collar to be the foremost issue related to clothing cutting. In other words, the clothing cutting of turnout gear should prioritize protection at the collar, with considerations to both safety and comfort.

Table 5. Risk decision factors relating to material.

Decision Construct (A)	Decision Factor (B)	Weight (A × B)	Rank
Material (0.186749)	High levels of toxicity (0.243913)	0.04555	9
	Short lifespan (0.087807)	0.01640	19
	Lack of flame-retardant fibers (0.264281)	0.04935	8
	Shrinkage after washing (0.107304)	0.02004	17
	No resistance to fouling (0.072347)	0.01351	21
	Difficulty to clean (0.090263)	0.01686	18
	Lack of reflectivity (0.134084)	0.02504	15
	Total weight sum = 1		

Table 6. Risk decision factors relating to cutting.

Decision Construct (A)	Decision Factor (B)	Weight (A × B)	Rank
Cutting (0.073938)	Insufficient protection at the collar (0.199514)	0.01475	20
	Unideal pocket design (0.054806)	0.00405	28
	Insufficient protection at the sleeve cuffs (0.150593)	0.01113	26
	Loose front fastenings (0.168525)	0.01246	23
	Poor fit in the legs and waist (0.109916)	0.00813	27
	Loose seams (0.162610)	0.01202	24
	Excessive joint tightness (0.154038)	0.01139	25
	Total weight sum = 1		

5. Risk decision factors relating to technology

Lack of an air filtration device (0.274980) was the highest risk factor among all technology domain factors and ranked 11th among all risk factors. Lack of an oxygen storage indicator (0.260081) was the second highest risk factor and ranked 13th among all risk factors. No display of respiratory or heartbeat data (0.196213) ranked 14th among all risk factors (Table 7). These results demonstrate that most experts prioritize equipping suits with air filtration devices within the technology domain. Fire scenarios may produce toxic substances and gases, with the smoke carrying high levels of toxins. Therefore, the incorporation of air filtration devices in the equipment design should be paramount.

Table 7. Risk decision factors relating to technology.

Decision Construct (A)	Decision Factor (B)	Weight (A × B)	Rank
Technology (0.138282)	Lack of heat sensors (0.171950)	0.02378	16
	No oxygen storage indicators (0.260081)	0.03596	13
	No display of respiratory or heartbeat data (0.196213)	0.02713	14
	Lack of falling or collision sensors (0.096776)	0.01338	22
	No air filtration device (0.274980)	0.03802	11
	Total weight sum = 1		

4.2. Risk Assessment

Firefighters work in a highly dangerous environment and often must respond to sudden changes to control risk. This will be discussed based on the risk factors within 73% of the cumulative weight, the shaded area in Table 8.

Insufficient flame resistance, insufficient heat resistance, putting on gear components in the wrong order, insufficient resistance to tears or punctures, and insufficient water resistance—which are ranked 1, 2, 3, 4, and 7, respectively—all belong to the protection decision construction and are high-risk factors of less than 60% tolerability, demonstrating the importance of protection. As such, protection should be prioritized among the five decision constructs in the design of turnout gear. The remaining risk decision factors were controlled within a 70% range of tolerability and, therefore, considered moderate. High toxicity ranked 9th, and short lifespans ranked 19th, indicating that the experts prioritized the clothing's safety over its durability (Table 8).

Table 8. Cumulative weight and ranking of decision risk factors.

Rank	Risk Decision Factors	Weight	Cumulative Weight
1	Insufficient flame resistance	0.11163	0.11163
2	Insufficient heat resistance	0.10949	0.22113
3	Putting on gear components in the wrong order	0.08489	0.30602
4	Insufficient resistance to tears or punctures	0.06590	0.37192
5	Poor agility	0.05163	0.42354
6	Heavy overall weight	0.05050	0.47404
7	Insufficient water resistance	0.05045	0.52449
8	Lack of flame-retardant fibers	0.04935	0.57384
9	High levels of toxicity	0.04555	0.61940
10	Insufficient internal circulation	0.04044	0.65984
11	No air filtration device	0.03802	0.69786
12	Poor air permeability	0.03610	0.73396
13	No oxygen storage indicators	0.03596	0.76993
14	No display of respiratory or heartbeat data	0.02713	0.79706
15	Lack of reflectivity	0.02504	0.82210
16	Lack of heat sensors	0.02378	0.84588
17	Shrinkage after washing	0.02004	0.86591
18	Difficulty to clean	0.01686	0.88277
19	Short lifespan	0.01640	0.89917
20	Insufficient protection at the collar	0.01475	0.91392
21	No resistance to fouling	0.01351	0.92743
22	Lack of falling or collision sensors	0.01338	0.94081
23	Loose front fastenings	0.01246	0.95327
24	Loose seams	0.01202	0.96530
25	Excessive joint tightness	0.01139	0.97669
26	Insufficient protection at the sleeve cuffs	0.01113	0.98782
27	Poor fit in the legs and waist	0.00813	0.99595
28	Unideal pocket design	0.00405	1.00000

5. Conclusions

Among the five decision constructs—protection, comfort, material, cutting, and technology—protection had a weight of 0.422366, the highest. This indicates that experts consider protection to be the paramount function of turnout gear. Material ranked second at 0.186749, and comfort ranked third at 0.178665. Technology ranked fourth with a weight of 0.138282. Cutting demonstrated a weight of 0.073938; experts appeared to consider cutting to be less of a priority than the other constructs, with the first-ranked construct, protection, having a weight 5.71 times that of the fifth-ranked construct, cutting.

In accordance with the *Handbook for Risk Management and Crisis Handling of the Executive Yuan and Affiliated Agencies* [43], a risk range of 80–100% is considered low risk and, therefore, negligible, a risk range of 60–79% is considered moderate risk and, therefore, acceptable, and a risk range of 59% or less is considered high risk and, therefore, unacceptable and requires improvements. As demonstrated in the cumulative weights and rankings of the risk decision factors, eliminating 12 of the 28 safety risk factors will result in 73% safety.

These 12 factors are, in order, insufficient flame resistance, insufficient heat resistance, putting on the suit components in the wrong order, insufficient resistance to tears and punctures, poor agility, heavy overall weight, insufficient water resistance, lack of flame-retardant fibers, high levels of toxicity, insufficient internal circulation, lack of an air filtration device, and poor air permeability.

The weight values of the risk factors were heavily skewed toward the top-ranking factors. The top three risk factors—insufficient flame resistance, insufficient heat resistance, and putting on the suit components in the wrong order—accounted for 30% of the overall weight, and the top seven risk factors—insufficient flame resistance, in-sufficient heat resistance, putting on the suit in the wrong order, insufficient resistance to tears and punctures, poor agility, heavy overall weight, and insufficient water resistance—accounted for 52% of the overall weight. The remaining 16 factors only accounted for 27% of the overall weight, a significant discrepancy in the distribution of the risk weight. The safety function requirements of fire protective clothing provide a weak case for the problem of sustainability. The experts agreed that the safety of materials is more important than the service life of clothing. However, some of these factors are listed among the municipalities' acceptance criteria for turnout gear and must be taken into consideration, despite their low weight scores. These factors are lack of reflectivity, shrinkage after washing, difficulty to clean, short lifespan, insufficient protection at the collar, lack of resistance to fouling, and insufficient protection at the sleeve cuffs.

In summary, the development of protective and technological materials with longer lifespans and changes to the cut of turnout gear to enhance joint flexibility could improve safety and comfort and extend its lifespan, resolving the problem of turnout gear exceeding its expiry. Although this study focused on the protective function and sustainability of fire protective clothing, the use of sustainable materials and ecofriendly manufacturing processes is also crucial to sustainability. Fire departments should consider these factors when purchasing fire protective clothing and contribute to protecting the Earth. Studies should also perform a cross-impact analysis of factors affecting the design of turnout gear and investigate the materials used in firefighter apparel.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14127040/s1.

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