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Comparison of Component Categorizations used in International Total Cost of Fire Estimates

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Highlights:

- Review of selected international approaches to categorize cost components
- Key cost components forming the total cost of fire were identified
- Influencing factors affecting categorization selection and approaches were noted
- The analysis contributes towards an updated Canadian total cost of fire

Abstract:

Key cost components forming the total cost of fire used in a selection of previous international studies have been identified and compared, with a future focus of revisiting the Canadian context. The potential influence of several factors on the selection and categorization of cost components was considered along with novel contributions to analysis approaches. End-user priorities (e.g. fire service, policy makers or insurance industry) may have an effect on the categorization approach due to specific interests, potential increased ease of access to data and intended applications of results. Selection of inputs may also be influenced by contextual aspects, including considerations of the local region (e.g. demographics, organization of the fire services or extent of insurance coverage) and timing (e.g. recent events, emerging fire safety challenges or trends). The availability, quality or lack of data then influences what estimation methodology may be best suited, as well as the categorization approach. Such examples of influencing factors make direct comparison of cost-of-fire estimates difficult; however, understanding the effects of these factors will contribute to developing an updated analysis that is applicable to the intended context and may include comparability to other studies or components of these, if useful.

Keywords: fire cost, cost estimation methodologies, impact assessment, risk assessment, economic assessment, preventative strategies, fire incident statistics

1. Introduction

National total cost of fire estimates may be used to identify areas of potential concern in fire risk management or to consider the cost effectiveness of potential fire protection solutions [1]; however, the analysis of total fire costs in the Canadian context [2] may not provide insights reflecting currently available data, societal expectations or developments of methodologies

because of the age of the analysis or level of detail. Therefore an updated Canadian context for the total cost of fire would assist in evaluating opportunities for, and potential impact of, research and regulation development. A related task to this is the consideration of the strengths and weaknesses of previous international total cost of fire estimates. This provides a collection of lessons learnt and approaches to address limitations to inform the development of an updated Canadian total cost of fire. A summary of selected component categorization approaches is presented, with the intent to provide a context for broader discussions on practical application, opportunities or limitations.

In this paper, the motivation for updating the total cost of fire is discussed (Section 2), before an overview is presented of selected international approaches to the selection and application of various cost categories and components (Section 3). Then, the selection and implementation of the cost categories for several key components are discussed (Section 4).

Parallel work is underway to investigate methodologies that include the consideration of the dependence on the quantity and quality of available data. The content of this paper, and subsequent discussions of the practicalities of the Canadian context to be facilitated by this, will contribute to the larger project of updating the Canadian total cost of fire.

2. Background

A national total cost of fire and its components are useful for a variety of purposes, including:

- providing a monetary estimate of the magnitude of the "fire problem";
- assisting in decision making and developing fire safety policies [3, 4];
- setting priorities in fire research programs [1, 5];
- comparing fire-related costs (or impacts) to other national challenges requiring investment, in support of optimizing the allocation of public and private resources used in fire prevention, mitigation and recovery [6, 7];
- assessing the impact of potential changes in fire safety regulations, e.g. comparing solution or strategy options [8, 9];
- tracking the effectiveness over time of a country's fire risk management strategy [10]; and
- facilitating international comparisons [11].

Additionally, understanding the entire scope of costs associated with fire may inform and stimulate development of more cost-effective fire safety measures [12], as well as evaluate how investments in fire protection can affect total costs [13]. While a national total cost of fire estimate and its components can be useful, standardization and other approaches may be needed to address consistency and comprehensiveness of available data within jurisdictions of one country [14] and among countries [11]. Considerations of the intended applications, available data, and the selection of components and methodology are interconnected.

3. Discussion of Previous Studies

Studies to be considered were selected based on available detail of the estimation methodologies. These are summarized in Table 1. Some countries (e.g. USA, England) have revisited and

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revised their estimates and the associated methodologies over time, while others (e.g. Canada) have not conducted recent comprehensive updates even though updated data for individual cost components may be available.

For the purposes of this discussion, the following terminology will be used: "Cost component" is an element of the total cost of fire that can ideally be quantified (and can be divided into subcomponents); the extent depends on available input data. "Cost category" describes one or more cost components or subcomponents. "Categorization approach" refers to the framework used to select and group cost categories.

Table 1. Selected Studies on the Total Cost of Fire

Country	Base Year	Sponsor	Lead Author	Ref.
USA	1989/90	National Institute of Standards and Technology (NIST)	W. Meade	[15]
USA	2011[a]	National Fire Protection Association (NFPA)	J. Hall, Jr.	[16]
USA	2014	NFPA	J. Zhuang	[17]
Canada	1991	National Research Council Canada (NRC)	P. Schaenman	[2]
England	2008[b]	Department for Communities and Local Government	Entec UK Ltd.	[18]
Australia	2005	Academia	B. Ashe	[19]
New Zealand	2004	New Zealand Fire Service Commission	M. Goodchild	[20]
Denmark	1998	Danish Emergency Management Agency	K. Møller (ed.)	[21]

Table 1 Notes: [a] Latest of a series by the same author. [b] Latest of a series by varying authors.

3.1 Key Cost Components

Descriptions of key cost components addressed by the studies in Table 1 include the following:

- Business Interruption, when considered on a local level, is the inability to return to business as usual following a fire, including permanent closing and temporary interruption. On a national level, this refers to the losses incurred when a consumer is unable to obtain the same good at a similar time and price.
- Environmental Impact concerns the damage to the environment due to release of materials during a fire event, as well as suppression and recovery operations. This could include health effects associated with environmental pollution.
- Fire Service considers costs involved in responding to fire emergencies, rescue and suppressing fires. This could include paid, volunteer, public and private services. It also includes capital costs (e.g. stations, vehicles, equipment) and operational costs (e.g. training).
- Human Casualties are the costs of injury and fatality to humans due to fire.
- Insurance Overhead is the cost of administering fire-related insurance. This typically does

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not include transfer payments by those paying premiums to those receiving claims payments.

- Preventative Measures are the costs of actions taken to reduce fire risk or mitigate damage caused by fire. This may include design changes, equipment and operational procedures.
- Property Loss is the damage to any type of property (including buildings, contents, infrastructure, and wildland) by fire or fire suppression efforts. This could include the cost of property deemed by society to have additional natural, heritage or cultural value.

Each cost component may be divided into subcomponents. For example, the Fire Service component has often been split into subcomponents representing paid and volunteer services. Furthermore, the studies label costs as direct and indirect with no consistent definition.

The above list of key components is by no means exhaustive in terms of covering all possible costs related to fire; they represent the most commonly used components. Other cost components have been considered, but are not commonly estimated in detail due to lack of robust data and may have been either included as an indication of order of magnitude or not included in any quantitative considerations. Typical components with large uncertainty include residential interruption (e.g. evacuation, temporary lodging), impact on real estate values, liability and litigation, the cost of police activities related to fire incidents (e.g. criminal investigation), and costs to the criminal justice system to investigate deliberate fires or major incidents.

3.2 Commonalities of Selected Studies

Table 2 is a simple indication of key cost components used in each of the studies in Table 1.

Table 2. Key Cost Components Considered in Previous Studies.

Cost Component	USA, Meade [15]	USA, Hall [16]	USA, Zhuang [17]	Canada [2]	England [18]	Australia [19]	New Zealand [20]	Denmark [21]
Property Loss	Y	Y	Y	Y	Y	Y	Y	Y
Business Interruption	Y	Y	Y	Y	Y	Y	Y	--[b]
Fire Service	Y	Y	Y	Y	Y	Y	Y	Y
Insurance Overhead	Y	Y	Y	Y	Y	Y	Y	Y
Preventative Measures	Y	Y	Y	Y	Y	Y	Y	Y
Human Casualties	--[a]	Y	Y	Y	Y	Y	Y	Y
Environmental Impact	--	--	--	Y	--	Y	--[b]	--

Table 2 Notes: [a] Cost component was discussed, but not included in the total cost of fire estimate. [b] Cost component was discussed, but not estimated due to lack of appropriate data.

In general, the studies from the USA [15, 16, 17] and Canada [2] are based on the approach employed by Meade [15], who considered five key components: Property Loss, Business

Interruption, Fire Service, Insurance Overhead and Preventative Measures. The more recent studies by Hall [16] and Zhuang [17] added Human Casualties. The Canadian study [2] had provided the most comprehensive analysis at the time, considering as many cost components as possible, including Human Casualties and Environmental Impact. However, due to lack of data, Business Interruption and Environmental Impact were combined under the more generic category of "Indirect Losses". Likewise, Meade [15] and Hall [16] combined estimates of Business Interruption with Property Loss under the category "Losses" or "Economic Loss", respectively, based on an assumed proportionality to Property Loss. Although Hall [16] described this method as "on shaky ground", no alternative method was proposed at the time.

Hall [16] addressed data quality and estimation methodology most directly in his categorization approach by grouping cost categories into core costs versus other costs. Core costs were those involving financial transactions that could be relatively easily determined on an annual basis, and included the components: Property Loss, Business Interruption, Fire Service, Insurance Overhead, and one subcomponent of Preventative Measures (Section 4.1).

In contrast, the studies from England [18], Australia [19] and New Zealand [20] followed a different categorization approach, grouping cost components chronologically: costs in anticipation, costs in response and costs as a consequence. (The New Zealand study used slightly different terminology; Table 3.) In general, costs in anticipation involved Insurance and Preventative Measures, costs in response involved Fire Service, and costs as a consequence involved Property Loss, Business Interruption, Human Casualties and Environmental Impact. This was conceptually similar to the categorization approach used by Zhuang [17], except that economic specific terminology was used, involving expenditures and losses (Table 3). Indirect expenditures were similar to costs in anticipation, direct expenditures were similar to costs in response, and losses (direct and indirect) were similar to costs as a consequence.

As another example of how the intended use of the results of a study can influence the categorization approach, the Danish study [21] grouped cost categories into costs reflecting community readiness, costs directly caused by fire, and secondary costs derived from fires. Costs reflecting community readiness involved Fire Service and Preventative Measures, while costs directly caused by fire involved Property Loss and Human Casualties (Table 3). In this case, the study was focused on the potential impact of investment in Fire Service and Preventative Measures (i.e. community readiness) on Property Loss. Consequently, Business Interruption and Insurance were considered to be secondary costs within that specific study.

3.3 Factors Influencing Selection and Categorization of Cost Components

As previewed above, the main factors influencing selection and categorization of cost components are: sponsor or intended end user (all stakeholders); country and its cultural context [22]; priorities of the time at which the cost estimate is made; and quantity and quality of available data [23]. More detailed discussion of these factors is provided in the next section.

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160 Table 3. Cost Categorization Approaches of Selected Studies.[a]

Cost Component	England [18]	Australia [19]	New Zealand [20]	USA, Zhuang [17]	Denmark [21]
Property Loss	Consequence	Consequence	Recovery and consequence	Direct loss	Directly caused by fire
Business Interruption	Consequence	Consequence	Recovery and consequence	Indirect loss	Secondary costs
Fire Service	Anticipation, Response	Response	Readiness and response	Direct expenditure	Community readiness
Insurance Overhead	Anticipation	Anticipation	Risk reduction	Indirect expenditure	Secondary costs
Preventative Measures	Anticipation	Anticipation	Risk reduction	Indirect expenditure	Community readiness
Human Casualties	Consequence	Consequence	Recovery and consequence	Direct loss	Directly caused by fire
Environmental Impact	--	Consequence	--	--	--

161 Table 3 Notes: [a] Meade's [15] and the Canadian [2] studies did not group components together.
162 Hall [16] grouped components as core and non-core costs. These are excluded here.

163 The sponsor or intended end user of cost-of-fire estimates has a direct effect on the focus on a
164 particular cost component, the effort put into determining accurate values and potential access to
165 the data. For instance, the New Zealand study [20] was sponsored by the Fire Service
166 Commission and contained separate cost categories relating to trial evacuations (fire drills),
167 municipal water supply systems and false alarms. Conversely, the English study [18] focused on
168 the cost of arson and thus included a category on the cost to the police and prison service.

169 Different countries (and different jurisdictions within a country) have different data collection
170 and classification methods that influence the way cost components are categorized. For instance,
171 the Danish study indicated that the cost of temporary housing after residential fires was covered
172 by insurance and thus combined this cost component with Property Loss in the same category,
173 whereas this may not be applicable elsewhere. Within the Canadian study, the cost of Property
174 Loss was seen to exhibit biases depending on whether the data was obtained from insurance
175 companies or fire departments, which made it difficult to estimate this cost component in a
176 consistent manner across the nation. Other regional differences may include: effects of varying
177 climates on building construction, organization and function of professional and volunteer fire
178 services, enforcement of fire safety codes and standards, and fire insurance coverage [7].

179 Priorities in fire protection change with time, affecting which cost components are selected at the
180 time of development of each study. For example, the recent rapid growth of development in the
181 wildland urban interface has highlighted the importance of wildland fire impacts and the costs
182 associated with evacuation and interruption to people's daily lives. This was not the case a few
183 decades ago, when initial estimates of the cost of fire were made. Due to lack of updated data,

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estimates from one-time studies (which may be decades old) are often adjusted for inflation and subsequently applied. The use of data, estimation methodologies and categorization approaches from earlier studies needs to be considered carefully, or at least clearly acknowledged, since their relevance to current technology and practices may have changed; therefore components may not have the same relative proportions and scaling relative to inflation alone may not be appropriate.

The structure of available data influences estimation methodology and component categorization. For instance, in the New Zealand study [20], estimates of direct losses related to Business Interruption were included in the same cost category as Property Damage and both were estimated based on insurance claims. The indirect losses estimated for businesses supplying a fire-damaged business were then considered under a separate cost category, rather than being combined with the direct losses related to Business Interruption of the fire-damaged business.

4. Further Discussion of Selected Key Cost Components

This section discusses in more detail the following: Preventative Measures, Fire Service and Environmental Impact. These were selected as they provide insight into aspects such as time context, regional context, data availability and stakeholder influence (Section 3.3).

4.1 Preventative Measures

Meade [15] considered six cost categories as part of Preventative Measures:

- "Built Into Structures" captured the cost of built-in fire protection in new building construction, accounting for active and passive measures required by building codes.
- "Built Into Equipment" accounted for the cost of built-in fire protection in equipment installed in new facilities (e.g. airports, hotels and factories) to achieve "fire-grade" design, and captured the increased costs needed to enhance regular commercial product designs (e.g. for telecommunications, computing, industrial and electrical equipment) to meet fire safety standards, such as those by Underwriters Laboratories.
- "Standards Activity" covered ongoing costs of voluntary codes and standards, including the preparation and maintenance of fire-related standards by the private sector.[1]
- "Fire Maintenance" included costs for routine maintenance of detection and suppression equipment, employee training, industrial brigades and private emergency response teams.
- "Retardants/Testing" captured the costs of formulation and application of fire retardant chemicals, as well as product and materials testing for flammability and toxicity.
- "Disaster Recovery" focused on costs of data protection to mitigate business interruption (e.g. computer backup services and fire suppression systems in computer facilities).

Some of these categories were selected based on the priorities of the time and would have also been influenced by the technologies and strategies available. Fire retardants and related testing were of significant concern at the time of Meade's study, coinciding with an emerging plastics

[1] Based on Meade's description, "fire-grade" designs could involve concurrent development of fire safety standards to address the unique scope and objectives (beyond building code applications) in order to permit certification; there may be the potential for an overlap of "Standards Activity" with "Built Into Equipment".

recycling industry, the use of brominated fire retardants and the understanding of the toxic gases generated during re-melting [24]. Protecting computer systems was also of major concern due to the immense growth of and dependence on the computing industry. Whether these categories are still required to be addressed separately or might be expanded to include more recently relevant aspects needs to be considered when revisiting a total cost of fire estimation.

Table 4 maps the cost categories to cost subcomponents that were quantified as part of Preventative Measures in the US [15, 16, 17] and Canadian [2] studies. Meade [15] used six categories to describe eight subcomponents, where "Fire Maintenance" and "Retardants/Testing" each covered two subcomponents. All other categories covered single subcomponents.

The subcomponents considered by Meade [15] were incorporated almost directly into the studies by Hall [16] and Zhuang [17]. Hall distinguished Fire Protection in Building Construction as a core cost (with available annual data). All the other subcomponents were non-core costs under the category "Other Economic Cost" and were estimated by scaling Meade's estimates. Zhuang [17] did not use the same cost grouping as Hall [16], but applied similar proportional estimation methodologies. The continued use of the subcomponents considered by Meade [15] and in most cases, his original estimates, indicates a lack of both updated data and evolution in methodology. As mentioned above, the selection and context of industry-specific subcomponents (Fire Retardants and Disaster Recovery) may not be as relevant today. This suggests that a renewed look at subcomponent selection, definition and categorization is warranted.

The Canadian study [2] attempted to be more comprehensive than Meade's by proposing additional subcomponents (Table 4) in the following cost categories:

- "Cost of Fire Protection in Structures" captured the costs of built-in fire protection in both buildings and infrastructure (e.g. bridges, roads, waterworks, powerplants and refineries), including maintenance costs.
- "Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations" described costs of fire safety built into everything other than structures, including the use of fire retardants (which was separated out by Meade [15]) and occupational fire safety training (part of Meade's "Fire Maintenance" category).
- "Miscellaneous Costs" included the costs associated with testing materials and equipment to fire safety standards, fire-related activities by codes- and standards-making agencies, fire research, and disaster recovery, as similarly identified by Meade [15].

The mapping of Preventative Measures cost categories and cost subcomponents for the selected studies from England [18], Australia [19], New Zealand [20] and Denmark [21] is summarized in Table 5. These studies did not include all of the subcomponents considered in the Canadian study [2]. This may be related to difficulties in obtaining data and deriving cost estimates. For instance, both the English and Danish studies focused on Fire Protection in Building Construction because

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Table 4. Cost Categories Related to Preventative Measures – USA and Canada.

Cost Subcomponent	Meade [15][a]	Hall [16][b]	Zhuang [17][b]	Canada [2][b]
Fire Protection in Building Construction	"Built Into Structures"	"New Building Costs for Fire Protection"	"Fire Safety Costs in Building Construction"	"Cost of Fire Protection in Structures"
Fire Protection in Infrastructure Construction	--	--	--	"Cost of Fire Protection in Structures"
Fire Protection in Consumer Products	"Built Into Equipment"	"Other Economic Cost"	"Fire Grade Products"	"Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations"
Codes/Standards	"Standards Activity"	"Other Economic Cost"	"Preparing/Maintaining Standards"	"Miscellaneous Costs"
System/Equipment Maintenance	"Fire Maintenance"	"Other Economic Cost"	"Fire Maintenance"	"Cost of Fire Protection in Structures"
Occupational Fire Safety Training	"Fire Maintenance"	"Other Economic Cost"	"Fire Maintenance"	"Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations"
Fire Retardants	"Retardants/Testing"	"Other Economic Cost"	"Fire Retardants"	"Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations"
Product Testing	"Retardants/Testing"	"Other Economic Cost"	"Fire Retardants"	"Miscellaneous Costs"
Disaster Recovery	"Disaster Recovery"	"Other Economic Cost"	"Disaster Planning"	"Miscellaneous Costs"
Research	--	--	--	"Miscellaneous Costs"

Table 4 Notes: [a] Cost categories are taken from Table 2 on page III-24. [b] Cost categories are taken from the executive summary.

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Table 5. Cost Categories Related to Preventative Measures – England, Australia, New Zealand and Denmark.

Subcomponent	England [18][a]	Australia [19][b]	New Zealand [20][b]	Denmark [21][b]
Fire Protection in Building Construction	"Cost of Fire Protection in Buildings"	"Fire Safety in Buildings"	"Protection Measures in Buildings"	"Cost of Prevention"
Fire Protection in Infrastructure Construction	--	"Fire Safety Measures in Structures and Infrastructure"	"Reticulated Water Supply Systems"	--
Fire Protection in Consumer Products	--	"Fire Safety in Consumer Items"	"Protection Measures in Products"[c]	--
Codes/Standards	--	--	--	--
System/Equipment Maintenance	"Cost of Fire Protection in Buildings"	"Maintenance of Fire Safety Equipment and Measures"	--	--
Occupational Fire Safety Training	--	"Fire Safety Education and Training"	"Safety Regulations and Compliance"	--
Fire Retardants	--	--	--	--
Product Testing	--	--	--	--
Disaster Recovery	--	--	--	--
Research	--	"Fire Research"	--	--

Table 5 Notes: [a] Cost categories are taken from Table 8. [b] Cost categories are taken from the section headings. [c] This subcomponent was discussed, but not estimated due to lack of appropriate data and/or estimation methodology.

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data was most readily available for this subcomponent in the context of each study. However, the English data combined maintenance costs with construction costs, so the same cost category covered two subcomponents (Table 5). Meanwhile, the New Zealand study considered specific aspects of two other subcomponents, Occupational Fire Safety Training and Fire Protection in Infrastructure Construction, that were of particular interest to the study's sponsor, the New Zealand Fire Service Commission. Efforts were made to obtain data and calculate costs associated with establishing building evacuation schemes and conducting trial evacuations ("Safety Regulations and Compliance"), as well as constructing higher capacity municipal water supply systems in order to meet fire flow requirements ("Reticulated Water Supply Systems"). Although these cost categories addressed only part of the related cost subcomponent, their inclusion provides insights into how a study's stakeholder priorities may influence the categorization approach, where stakeholders may include funding sources or sponsors, end users and organizations providing data.

Of the studies mapped in Table 5, the Australian study [19] was the most comprehensive in terms of the number of cost subcomponents considered. The industry-specific subcomponents considered by Meade [15] (Fire Retardants, Product Testing and Disaster Recovery) were not explicitly included and were likely implicitly combined with other subcomponents (e.g. Fire Retardants and Product Testing were likely an implicit part of Fire Protection in Consumer Products). However, the Australian study evaluated the latter subcomponent by scaling the estimates from other countries (Canada [2] and Meade [15]), indicating that insufficient Australian data was likely available.

Based on the above discussion, the most appropriate subcomponents to be considered going forward appear to be: Fire Protection in Building Construction, Fire Protection in Infrastructure Construction, Fire Protection in Consumer Products, Codes/Standards, System/Equipment Maintenance, Occupational Fire Safety Training, and Research. Additional cost subcomponents may be needed to address emerging areas of concern, such as wildfire preparedness; this depends on the specific context and scope of each future study. Given the experience with Meade's industry-specific subcomponents, however, any new subcomponent must be defined carefully to avoid potential overlap by multiple subcomponents.

4.2 Fire Service

A variety of cost subcomponents related to Fire Service were included in selected studies, as presented in Table 1; the main ones being: Paid Fire Service, Volunteer Fire Service, Industrial Fire Brigades, Wildland Firefighting, and False Alarms. A mapping of these cost subcomponents to the cost categories used in each study is provided in Tables 6 and 7.

Almost all studies accounted for both Paid Fire Service and Volunteer Fire Service. Some studies used the same cost category for both subcomponents, while others used separate cost categories. This reflects the range of how fire services are organized in different countries (e.g. in Denmark, fire services are part of general emergency response services [21]). The use of separate categories in the studies by Meade [15], Hall [16], Zhuang [17] and the Australian study [19]

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302 Table 6. Cost Categories Related to Fire Service – USA and Canada.

Subcomponent	Meade [15][a]	Hall [16][b]	Zhuang [17][b]	Canada [2][b]
Paid Fire Service	"Fire Service – Paid"	"Local Fire Department Expenditures"	"Local Fire Department Expenditures"	"Cost of Fire Services"
Volunteer Fire Service	"Fire Service – Volunteer Conversion"	"Local Fire Department Expenditures" (equip.); "Cost of Coverage by Career Firefighters of Areas Now Protected by Volunteer Firefighters" (labour)	"Local Fire Department Expenditures" (equip.); "Value of Donated Time of Volunteer Firefighters" (labour); "Donations to Fire Departments"	"Cost of Fire Services"
Industrial Fire Brigades	"Fire Maintenance"	"Other Economic Cost"	"Fire Maintenance"	--
Wildland Firefighting	--	"Other Economic Cost"	--	"Cost of Fire Services"
False Alarms	--	"Local Fire Department Expenditures"	--	"Cost of Fire Protection in Equipment, Vehicles, Goods and Industrial Operations" (opportunity cost)

303 Table 6 Notes: [a] Cost categories are taken from Table 2 on page III-24. [b] Cost categories are taken from the executive summary.

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306 Table 7. Cost Categories Related to Fire Service – England, Australia, New Zealand and Denmark.

Subcomponent	England [18][a]	Australia [19][b]	New Zealand [20][b]	Denmark [21][b]
Paid Fire Service	"Capital Costs"; "Resource Costs"; "Resource, Capital and Non-Pay Related Costs"	"Fire Service Response Costs"	"Fire Emergency Services"	"Cost of Emergency Preparedness"
Volunteer Fire Service	--	"Volunteer Fire Service"	"Fire Emergency Services"	"Cost of Emergency Preparedness"
Industrial Fire Brigades	--	"Private Fire Brigade Response"	"Fire Emergency Services"	"Cost of Emergency Preparedness"
Wildland Firefighting	--	"Volunteer Fire Service"	--	--
False Alarms	"Resource Costs"	"Fire Service Response Costs"	"False Alarms" (includes opportunity cost)	--

307 Table 7 Notes: [a] Cost categories are taken from Tables 8 and 10. [b] Cost categories are taken from the section headings.

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may relate to the large contribution played by the volunteer fire service in the US and Australia. Different data sources and methodologies were also used between the separate categories. For instance, in Hall's approach [16], the cost of equipment purchased by volunteer fire departments was included in the data for the paid fire service, so the category "Local Fire Department Expenditures" (a core cost) described both the Paid Fire Service and the equipment aspect of the Volunteer Fire Service. The labour aspect of the Volunteer Fire Service was then estimated separately as a non-core cost. Zhuang [17] used the same data source as Hall [16] and thus maintained the same separation of categories, but added another category to cover donations to volunteer fire departments, which were not included by Hall [16].

As an example of how sponsor priorities might influence cost categories, the sponsors of the English study [18] were particularly interested in the cost of arson [25]. As a result, the Paid Fire Service subcomponent was split into costs that would occur regardless of the number of reported fires ("Resource, Capital and Non-Pay Related Costs") and those that were directly related to responding to fire incidents ("Capital Costs" and "Resource Costs"). Under the categorization approach used in the study (Table 3), the former (which included pension contributions, training, community fire safety activities, and fire inspections) were considered to be costs in anticipation, while the latter were considered to be costs in response. This separation of costs would allow the end user to estimate the additional cost imposed by deliberate fires.

Another area in which sponsor priority affected component categorization is False Alarms. In general, the cost of responding to false alarms either was included in the cost category related to Paid Fire Service (e.g. Hall [16], England [18], Australia [19]) or was not considered to be fire-related and excluded (Zhuang [17]). However, the Canadian study [2] incorporated an estimate of the opportunity cost to businesses. The New Zealand study [20] distinguished False Alarms as a separate cost category, with consideration of the costs to respond to and reduce false alarms, plus the opportunity cost to businesses of avoidable operational downtime. This separation from other cost categories was likely due to interest from the study sponsor, the New Zealand Fire Service Commission.

The variation in categorization of the Fire Service subcomponents illustrates the complexity of making cost estimations and the difficulty in comparing across studies. Therefore, it is important to identify and engage the intended stakeholder (especially end users), and assess their expectations, needs and objectives, early in the development of a total cost of fire estimate.

4.3 Environmental Impact

The Environmental Impact component was not addressed by most of the studies in Table 1. However, it is acknowledged as a topic of increasing priority, given the recent interest in wildland-urban-interface fires and carbon emissions [26, 27, 28]. This component could include: environmental damage from fires and suppression agents (e.g. atmospheric pollution, water runoff), landfilling of waste generated from fires, and health effects associated with air and water pollution. The value of property loss associated with outdoor fires and the cost of water used for firefighting could also be considered here or as part of other components.

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Data limitations have affected, and likely will continue to impact, the estimations of cost for this component [23]. For instance, Thomas et al. [26] identified seven types of environmental losses associated with wildfires, but was able to quantify only two of them. Nonetheless, estimating a cost for Environmental Impact is needed in order to accommodate increasing public interest in conservation of ecological systems and protection of human health [6, 28]. Thus engagement of the stakeholders may be critical to enabling access to useful data. Another consideration may be the use of multiple metrics (e.g. ecopoints [8], hours of effort, lives saved or fatalities) that may be mapped to a single monetary metric at the end of the analysis.

5. Conclusions

Key cost components forming the total cost of fire have been identified based on selected international studies. Comparison of these studies has illustrated the influence of the following critical factors on the selection and categorization of cost components: the interests, priorities and objectives of stakeholders (e.g. end users, study sponsors), the context of the country for which the cost estimate is made, the context of the time at which the cost estimate is made, and the completeness and quality of available data. Considerations of these factors are interconnected with the selection of cost components, estimation methodologies and overall framework.

Moving forward, cost categories would ideally be standardized, but this may be limited by data availability, at least in the short term. Regardless, the use of data, estimation methodologies and categorization approaches from earlier studies needs to be considered carefully in order to identify continuing useful insights or comparability versus elements that may no longer be appropriate for the current context. These aspects are recommended to be included in initial discussions with potential stakeholders of an updated Canadian cost of fire estimate. Additionally, discussions with research organizations outside Canada interested in the cost of fire may enable alignment and, thus, enhance the ability for comparison of cost of fire data from different countries.

6. Recommendations for Next Steps

While this paper provides a summary of a portion of the information forming the basis of the scoping phase of the larger research project, it is complemented by next steps that are underway, including a detailed investigation of previous studies and engagement of potential end users, data owners, collaborators and other interested parties. This intentional engagement of the fire safety community and cost estimation experts is focused on sharing current developments, previous lessons learned, and options for on-going participation that will inform the planning of the overall project. Interested parties can contact the lead author for more details.

Future development of an overall total cost of fire estimate is likely to take a modular approach, using a framework of manageable work packages based on key cost components. This would allow participating collaborators to focus on their area(s) of interest, and modules to be developed in series or parallel while still contributing to the overall total cost of fire estimate. Such an approach would allow for one module to be developed as an initial demonstration of concept that would form the kick-off for the development phase of the project.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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