Actuariat et construction en bois massif

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Abstract

Plan du résumé :

1. *Background*
2. *Aims / General Objective/ Findings*
3. *Methods*
4. *Results and conclusions*

Keywords : ...

Nom du fichier: main.tex

Contents

1 Introduction

L'assurance représente un outil majeur pour la gestion du risque dans un projet de construction.

[...]

1.1 Contexte

Points importants:

- Les membres de la Chaire CIRCERB cherchent a évaluer le juste prix de protection d'assurance pour les constructions en bois massif, comme le CLT (*Cross-laminated timber*);
- Les primes d'assurance proposées par les compagnies d'assurance privées pour ce genre de protection sont très élevées et limitent fortement le développement de cette industrie;
- Les membres de la Chaire CIRCERB estiment de plus que les primes proposées par les compagnies d'assurance sont trop hautes par rapport au risque réel.

En théorie, dans un marché ouvert et compétitif où il existe de nombreux assureurs, puisque les assurés auront toujours tendance à choisir l'assureur qui offre la prime la moins élevée, on devrait s'attendre à ce que les primes d'assurance convergent vers le risque réel [1]. Toutefois, il arrive occasionnellement que ce qu'on appelle le phénomène d'anti-sélection ne soit pas toujours observé en pratique:

- Le nombre d'assureurs réellement intéressés à un certain secteur d'activité peut être limité;
- Le produit à assurer est parfois peu connu, peu fréquent sur le marché et une période de temps assez longue est souvent nécessaire aux assureurs pour collecter, analyser les résultats de sinistralité et déterminer une prime d'assurance proche du risque réel.

La situation actuelle de l'assurance des constructions en bois massif, incluant le CLT, semble correspondre à ces derniers éléments.

Cet aspect est soulevé notamment dans la monographie [Syed, 2020] : "Mass timber construction in Canada is in the spotlight and emerging as asustainable building systemthat offersan opportunity to optimize the value of every tree harvestedandtorevitalize a declining forest industry, while providing climate mitigation solutions.Little research has been conducted, however, to identify the mass timberresearch prioritiesof end users, barriersto adoptionand engineering, procurement and construction challenges in Canada. This study helpsbridge thesegaps.The study also createdan interactive, three-dimensional GIS map displaying mass timberprojects across North America, as an attempt tooffer a helpful tool to practitioners, researchers and students, and fill a gap in existing knowledgesharing.The study findings, based on aweb-based surveyof mass timber end users, suggest the need formore research on (a) total project cost comparisonswith concrete and steel, (b) hybrid systemsand(c) mass timber building construction methodsand guidelines. The most important barriers forsuccessfuladoption are (a) misconceptionsabout mass timber with respect to fire and building longevity, (b) highanduncertain insurance premiums, (c) higher cost of mass timber products comparedto concrete and steel, and (d)resistance to changing from concrete and steel.In terms ofchallenges:(a) building code compliance and regulations, (b) design permits and approvals, and (c) insufficient design experts in the market are rated by study participants asthemost pressing "engineering" challenge.The top procurementchallenges are(a) too few manufacturesand suppliers,(b)long distance transportation,and (c) supply and demand gaps.The most importantconstruction challenges are (a) inadequate skilled workforce, (b) inadequate specialized subcontractors, and (c) excessive moisture exposure during construction."

[1] En considérant les frais administratifs, les taxes et les profits.

1.2 Plan du document

Le présent document est construit comme suit : ...

2 Assurances IARD

2.1 Brève description du marché

L'industrie des assurances IARD est divisée en deux grands secteurs d'activités :

- lignes personnelles : principalement assurance automobile et habitation
- lignes commerciales (différents produits d'assurance)
  - propriété commerciale (assurance d'entreprise)
  - responsabilité
  - autres

L'assurance construction est un exemple d'assurance commerciale

Les principaux acteurs sont :

- Sociétés de courtage et sociétés de gestion d'assurances
- Compagnies d'assurance
- Compagnies de réassurance

On retrouve des faits sur les assurances IARD sur les sites des organismes suivants :

- Bureau d'assurance du Canada http://www.ibc.ca/ns/
- US: Insurance Information Institute http://www.ibc.ca/ns/

Les principaux secteurs d'activité des compagnies d'assurances IARD en 2019 sont :

Secteurs d'activité	Primes nettes souscrites
Assurance automobile (lignes personnelles)	43%
Assurance habitation (lignes personnelles)	23%
Assurance commerciale	14%
Assurance responsabilité civile professionnelle	10%
Autres	10%

Les valeurs sont similaires pour les compagnies américaines d'assurances IARD

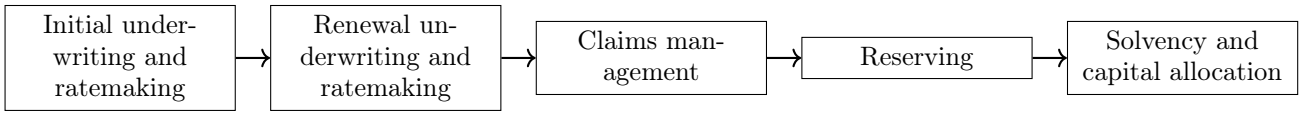


Illustration 1 – Principales unités opérationnelles d'une compagnie d'assurances IARD

2.2 Opérations d'une compagnie d'assurance IARD

Un excellent et bref aperçu des activités d'assurance dommages se trouve dans [Frees, 2015]. En peu de pages, l'auteur présente les enjeux d'une compagnie d'assurance dommages selon une perspective actuarielle et analytique.

Les cinq principales unités opérationnelles d'une compagnie d'assurances IARD (voir Illustration 1) sont les suivantes :

1. Souscription initiale et tarification
2. Renouvellement de la souscription et tarification
3. Gestion des règlements de sinistres
4. Calcul des provisions (provisionnement)
5. Solvabilité et allocation de capital

Les actuaires IARD sont principalement impliqués dans les items 1, 2, 4 et 5.

En tarification (items 1 et 2), l'actuaire vise à établir la prime d'une police d'assurances IARD.

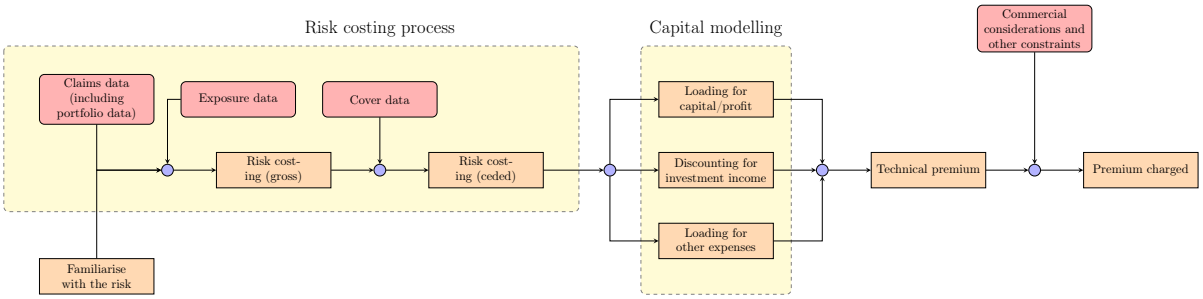


Illustration 2 – Vue d'ensemble du processus de tarification en assurance IARD

2.3 Processus de tarification actuarielle en assurance IARD

Le processus de tarification est crucial, car les primes d'assurance sont les principaux revenus des compagnies d'assurances IARD

Objectif du processus de tarification : établir la prime chargée pour une police d'assurance

Références sur la tarification actuarielle :

- Assurance IARD : [Parodi, 2014]
- Assurance IARD aux particuliers : [Ohlsson and Johansson, 2010], [Denuit et al., 2007]
- Assurance IARD aux entreprises : [Michaelides et al., 1997]
- Réassurance: [Albrecher et al., 2017], [Clark, 1996]

Comme l'explique l'auteur de [Parodi, 2014], les principales étapes du processus de tarification sont les suivantes :

1. Processus de souscription : se familiariser avec le risque et, pour l'assurance / réassurance commerciale, avec l'activité de l'assuré.
2. Processus d'établissement des coûts : estimer le coût du risque assuré sur la base des données disponibles
3. Chargement des dépenses de fonctionnement de l'entreprise (souscription, gestion des sinistres, paie, etc.)
4. Prise en compte des revenus de placement (*actualisation*)
5. Chargements pour le profit et l'exigence de capital

Prime technique = [2] + ... + [5]

Prime chargée = Prime technique + marge pour des considérations commerciales

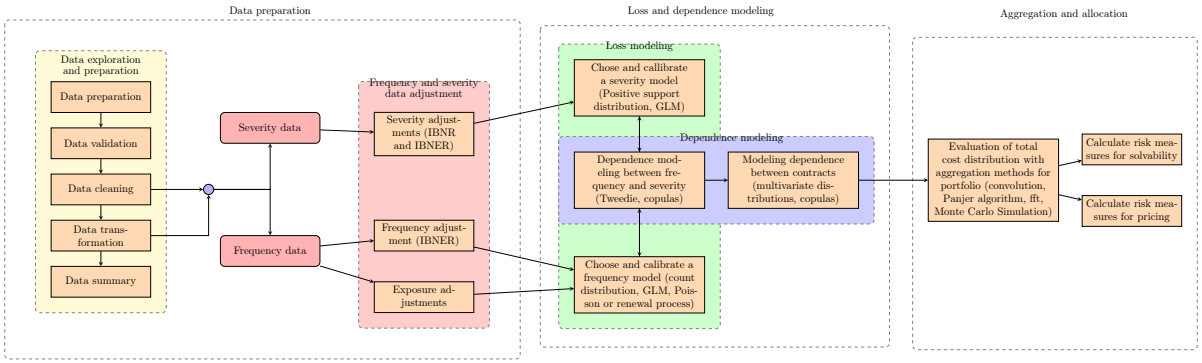
Le "processus de tarification" est réalisé en lien avec le "processus de provisionnement" et le "processus de solvabilité et d'allocation du capital"

On présente une vue d'ensemble du processus de tarification en assurance IARD à l'illustration 2.

Dans ce document, nous nous limiterons à l'étape [2] "processus d'établissement des coûts"

Généralement, le processus d'établissement des coûts en [2] est basé sur des modèles actuariels, appelés modèles fréquence-sévérité

Vue d'ensemble du processus de calcul des coûts des risques :



Procédure de tarification : fréquence-sévérité

2.4 Analysing the disconnect between the reinsurance submission and global underwriters' needs

Ce document est intéressant : [Buchanan et al., 2016].

Auteur principal : Buchanan (Verisk = ISO)

2e auteur principal : Enrico Biffis (grosse pointure en actuariat).

Le glossaire de l'annexe E est instructif : "Appendix E Property per Risk Acronym Reference"

Voir aussi annexe D : "COPE: Construction Class Cheat Sheet"

Résumé : "This research paper is intended to fill the void in the currently available actuarial literature related to information required by the reinsurance underwriter but often lacking when pricing property per risk coverages worldwide. Results from surveys of members in the UK, European and US actuarial communities, as well as others in the related insuring communities, clearly indicated a distinct disconnect between the information desired by reinsurers and the information commonly included within a cedent's submission. Underwriters are unable to refine the pricing of a contract because of this disconnect. Complicating the matter is the fact that this disconnect can occur in one or several steps in the transaction, beginning with the retail agents and/or brokers up through any level of reinsurer. Primary insurance carriers use the information collected by their retail agents or the insured's broker for their own underwriting purposes. The insurance carrier then decides what and how much of that information is provided to the reinsurer. Assumptions are made at each level. The agent or broker assumes it has provided the information wanted and needed by the primary insurance carrier because a policy is offered. Likewise, the primary insurance carrier assumes it has provided the requisite information to the reinsurer because a contract is offered. These assumptions affect pricing. Rather than allowing such assumptions to continue (that the information provided is sufficient and correct), this research paper attempts to specify what information is important to the reinsurer. When primary insurance carriers know what is important to the reinsurer, they can gather that information from the agent or broker. This paper results in a top down approach to improved property underwriting and pricing. When assumptions do not have to be made, pricing reflects the true exposure. Subject to the market constraints detailed in Chapter 13, every level wins: the insured gets the best pricing available from the insurance carrier because the primary insurance carrier gets the best pricing from the reinsurers."

3 Gestion du risque et assurance

La gestion du risque est complémentaire à l'actuariat.

Sommairement, la gestion du risque propose une approche qualitative à la compréhension et "gestion" du risque, alors que l'actuariat modélise quantitativement le risque pour évaluer les coûts de différentes stratégies pour gérer le risque.

Structure de la section:

- Le titre de la sous-section est le titre de l'article (ou du document).
- On a reproduit le résumé et fait de brefs commentaires.

3.1 Fundamentals of risk and insurance

Pour un exposé détaillé et assez récent sur la gestion du risque et à l'assurance, on recommande [Vaughan and Vaughan, 2007].

Définition du risk management (page 16 de [Vaughan and Vaughan, 2007]) : Risk management is a scientific approach to dealing with risks by anticipating possible losses and designing and implementing procedures that minimize the occurrence of loss or the financial impact of the losses that do occur."

Dans l'introduction (page 17 et plus, à partir de "RISK MANAGEMENT TOOLS") de [Vaughan and Vaughan, 2007], on classifie les approches pour gérer le risque comme suit :

1. risk reserves
2. risk avoidance
3. risk reduction
4. risk transfer
5. risk sharing

Dans le chapitre 31 de [Vaughan and Vaughan, 2007], j'ai trouvé cet extrait : "Commercial property coverage is the term used by the ISO to designate those fields previously known as "fire and allied lines." Because the term commercial property insurance (or commercial property coverage) is also used in reference to the range of coverages that provide protection on property of commercial risks (i.e., fire and allied lines, boiler and machinery, plate glass, marine, and crime insurance), this creates a potential for ambiguity. To minimize the confusion, we will follow the ISO's usage of the term commercial property coverage to refer to the traditional fields of fire and allied lines, and will use the term commercial property insurance when referring to the broad field of property insurance coverages."

Le contenu du chapitre 31 aide à comprendre la structure des contrats en assurance commerciale.

Dans l'extrait, on mentionne clairement l'importance du péril incendie.

newpage

3.2 Risk management and insurance

Cet ouvrage [Harrington and Niehaus, 1999] aborde la gestion du risque et l'assurance.

Par contre, il n'aborde par l'assurance construction, voire l'assurance commerciale.

Conclusion : pas utile pour nous.

3.3 Handbook of insurance

Cet ouvrage [Dionne et al., 2013] aborde la gestion du risque et l'assurance.

Par contre, il n'aborde par l'assurance construction, voire l'assurance commerciale.

Conclusion : pas utile pour nous.

Résumé: "This new edition of the Handbook of Insurance reviews the last forty years of research developments in insurance and its related fields. A single reference source for professors, researchers, graduate students, regulators, consultants, and practitioners, the book starts with the history and foundations of risk and insurance theory, followed by a review of prevention and precaution, asymmetric information, risk management, insurance pricing, new financial innovations, reinsurance, corporate governance, capital allocation, securitization, systemic risk, insurance regulation, the industrial organization of insurance markets, and other insurance market applications. It ends with health insurance, longevity risk, long-term care insurance, life insurance financial products, and social insurance."

3.4 Theory and practice of insurance

Cet ouvrage [Outreville, 1998] aborde la gestion du risque et l'assurance.

Par contre, il n'aborde par l'assurance construction, voire l'assurance commerciale.

Conclusion : pas utile pour nous.

Résumé: "Insurance is a concept, a technique, and an economic institution. It is a major tool of risk management, and plays an important role in the economic, social, and political life of all countries. Economic growth throughout the world has even expanded the role of insurance. emTheoryem emand Practice of Insuranceem aims to describe the significance of insurance institutions, the reasons they exist and how they function. The author emphasizes fundamental principles in risk and insurance, using an international frame of reference. This volume begins with an introduction to the concept of risk, then proceeds to cover insurance and its relationship to the economy; the principles of risk management and insurance; and the characteristics and performance of insurance companies."

4 Réassurance

4.1 Bases

Une excellente introduction sur les aspects actuariels et statistiques de la réassurance est donnée dans [Albrecher et al., 2017].

Une compagnie d'assurance vise à prendre des risques (d'assurance).

Pour gérer son risque global d'assurance, une compagnie d'assurance choisit d'en transférer une partie vers une ou des compagnie(s) de réassurance.

Le transfert des risques par le biais de contrats de réassurance contribue à améliorer le profil de risque des compagnies d'assurance.

Les principales motivations de la réassurance (pour une compagnie d'assurance) ([Albrecher et al., 2017]):

1. Réduire la probabilité de subir des pertes difficiles à assumer
2. Stabiliser les résultats commerciaux
3. Réduire le capital requis
4. Augmenter la capacité de souscription
5. Accéder à des *pools* de diversification plus importants
6. Recevoir de l'assistance dans l'évaluation, la tarification et la gestion des risques
7. Permettre à des risques d'être assurés qui autrement ne seraient pas assurables

La réassurance est cruciale pour l'assurance construction.

Dans les notes de cours suivantes (de l'ETH), l'auteur, chercheur de Swiss Re, offre un bel aperçu de la tarification en réassurance : [Antal and Re, 2007] (aussi citée dans [Albrecher et al., 2017]).

4.2 Réassurance et construction

[...]

4.3 Réassurance et bois massifs

[...]

5 Modélisation actuarielle et tarification en assurance IARD

5.1 Modèle fréquence-sévérité

Pour décrire le comportement des coûts pour un contrat d'assurance, les actuaires utilisent un modèle appelé fréquence-sévérité.

Le montant total des coûts en sinistres pour une police d'assurance IARD est représenté par une variable aléatoire (v.a.) X.

Caractéristique importante de la v.a. X :

- la v.a. X prend la valeur zéro avec une probabilité très élevée (selon le type de police)
- si une réclamation survient, le montant de la réclamation peut être très élevé (en particulier pour l'assurance commerciale (y compris la construction))

Modèle actuariel pour X = modèle fréquence-sévérité :

- fréquence : nombre de sinistres (v.a. positive discrète M)
- sévérité : si au moins un sinistre survient ($M > 0$) les montants de sinistres individuels (v.a positives continues B_1, B_2, B_3, ...)

La v.a. X est définie selon une somme aléatoire, i.e.,

$$X = \sum_{k=1}^{M} B_k.$$

Interprétation :

- $M = 0 \Rightarrow X = 0$
- $M = 1 \Rightarrow X = B_1$
- $M = 2 \Rightarrow X = B_1 + B_2$
- Etc.

Hypothèses classiques :

- A1: $\underline{B} = \{B_1, B_2, ...\}$ forme une suite de v.a. indépendantes
- A2: B_1, B_2, ... ont la distribution de probabilité que la v.a B
- A3: la suite de v.a. gravité $\underline{B}$ et la v.a. fréquence M sont indépendantes

Espérance de la v.a. montant total en coûts en sinistres X pour une police :

$$E[X] = E[M] \times E[B]$$

Interprétation:

- E[X] = prime pure de la police d'assurance
- coûts espérés pour une police = nombre espérés de sinistres (fréquence) $\times$ coûts espérés par sinistre (sévérité)

L'actuaire doit modéliser à la fois les distributions de la v.a. fréquence M et de la v.a. sévérité B

Exemple de distributions pour la v.a. fréquence M en assurance IARD :

- **distribution Poisson** : $M \sim Pois(\lambda)$
- $\lambda = E[M]$
- $\Rightarrow$ distribution du montant total des sinistres X = Poisson composée
- Assurance auto aux particuliers : $\lambda \approx 5\%$
- Assurance habitation aux particuliers : $\lambda \approx 1\%$

Dans l'illustration 3, on présente des courbes de fonctions de densité de distributions posssibles pour la v.a. sévérité B en assurance auto pour les particuliers : **distribution gamma** ($B \sim Gamma(\alpha, \beta)$)

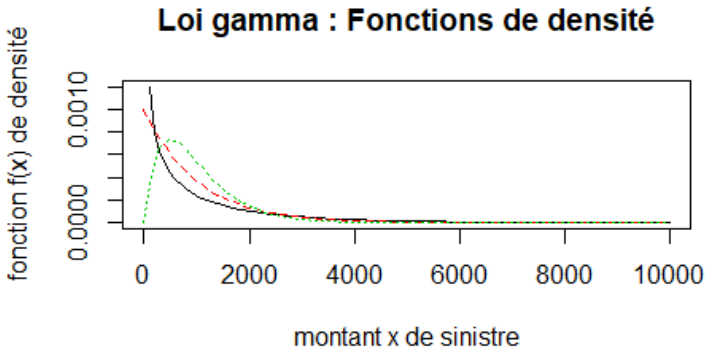


Illustration 3 – valeurs de $f_B(x; \alpha, \beta)$ pour $\alpha \in \{0.5, 1, 2\}$, tel que $E[B] = \frac{\alpha}{\beta} = 1000$

Interprétation : $\Pr(X \in (x, x + \mathrm{d}x]) = f(x)\mathrm{d}x$

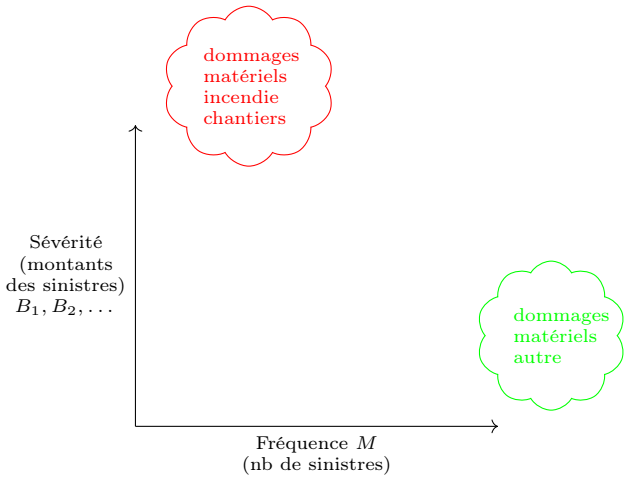


Illustration 4 – Modèle fréquence-sévérité : dommages assurance auto vs dommages matériels incendie chantiers

Source : Atelier Mon Sous-Sol (2021)

5.2 Assurances IARD aux particuliers

En assurances IARD aux particuliers, l'actuaire peut choisir (1) de modéliser la distribution de X ou (2) de modéliser séparément les distributions de M et de G

Pour les deux options, les paramètres des distributions sont estimés en termes de m caractéristiques ("features") $\underline{y} = (y_1, ..., y_m)$

Caractéristiques en assurance auto : type de véhicule, âge du conducteur/trice, etc.

Caractéristiques en assurance habitation : type de construction, distance des services d'incendie, etc.

De nos jours, les actuaires effectuent l'estimation des paramètres des distributions en termes de caractéristiques $\underline{y}$ en utilisant la méthodologie GLM (*Generalized Linear Models*)

Exemple: Modèle Poisson avec régression :

- Considérons n polices avec différentes caractéristiques $\underline{y}$
- $M \sim Pois(\lambda)$
- $\ln(\lambda) = \beta_0 + \beta_1 y_1 + ... + \beta_n y_m$
- $\beta_0, \beta_1, ..., \beta_m$ sont les paramètres de la distribution à être estimatés
- Cette approche nécessite un grand ensemble de données
- L'ensemble de données est mis sur pied par l'assureur

Les données sont cruciales en assurance IARD $\Rightarrow$ actif très important pour une compagnie d'assurance

Références: [Denuit et al., 2007], [Ohlsson and Johansson, 2010], [Frees et al., 2014], etc

Il existe de nombreuses extensions à la méthodologie GLM

5.3 Apprentissage automatique

La méthodologie GLM est un cas particulier des méthodologies que l'on trouve dans l'apprentissage automatique.

Les algorithmes d'apprentissage automatique sont capables de modéliser des transformations et des interactions hautement non linéaires d'entités d'entrée.

Alors que les actuaires utilisent fréquemment les GLM dans la pratique, ce n'est qu'au cours des dernières années qu'ils ont commencé à étudier ces des algorithmes pour aborder les tâches liées à l'assurance, en particulier en assurance IARD aux particuliers.

Dans les ouvrages suivants, leurs auteurs présentent une introduction l'intégratrion des outils de l'apprentissage automatique à la modélisation actuarielle :

- [Denuit et al., 2019]: trois tomes ; le risque de construction n'est pas examiné dans cette référence.
- ...
- ...

5.4 Illustration

On présente à l'illustration 5 les trois principales compétences d'un actuaire.

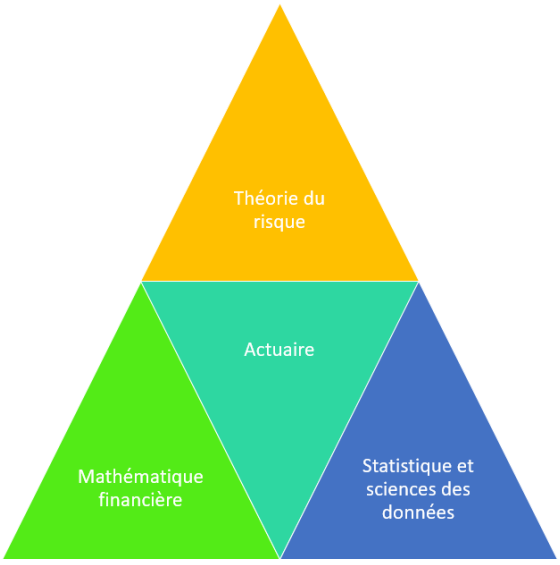


Illustration 5 – Principales compétences d'un actuaire

6 Assurance construction/chantier

6.1 Contexte

L'assurance construction est un exemple spécifique de l'assurance multirisque commerciale ([Lynch, 2006])

Les couvertures propriété et responsabilité sont les deux principales catégories d'assurance commerciale

Deux principales polices d'assurance

- Builder's Risk Insurance:
  - Type of property insurance designed for the construction industry
  - Covers the project owner and contractors for their labour, equipment, and building materials
- Wrap Up Liability:
  - Type of liability insurance designed for the construction industry
  - Covers owners, contractors and subcontractors.

6.2 An expert system for strategic control of accidents and insurers' risks in building construction projects

Remarques par [Imriyas, 2009] concernant l'assurance construction/chantier :

- "Construction is one of the most dangerous and risky businesses"
- "Insurance is a keystone to eliminate most of the financial risks in construction"

Résumé: "Building construction projects appear to have higher accident rates. Contractors procure workers' compensation insurance (WCI) to transfer these risks to insurance companies. The commitment of insurers under WCI is extremely broad; there are no exclusions and ceilings on their liabilities. They must quote adequate premiums to cover future risks. Yet, the prices should be low enough to penetrate the market. Thus, accomplishing rigorous risk and market assessments to decide optimal premiums for building projects is crucial. Traditionally, experience rating approach has been adopted for WCI premium-rating. However, this approach has been found ineffective for construction. Hence, the purpose of this study is to develop an effective WCI premium-rating model for building projects, and to automate the model as an expert system. A new WCI premium-rating model was developed based on the findings of a literature review and a questionnaire survey. A hybrid of interviews and past workers' compensation claims data analysis was pursued to develop the conceptual model of a fuzzy expert system to automate the proposed model. It was then prototyped and verified with Turing tests. The proposed expert system advocates real-time assessments of project hazards, safety, market conditions and insurers' internal factors for premium-rating. It also establishes an effective risk control strategy via a well-structured incentive system for contractors and clients. Its implementation in the insurance industry can curtail accidents in the construction industry, thereby minimising insurers' financial risks."

Cet article porte sur l'assurance compensation liée aux accidents de travail sur des chantiers de construction.

Conclusion : il n'est pas pertinent pour nous.

6.3 Risk and insurance in construction

Des détails sur les risques et les assurances dans la construction d'un point de vue juridique peuvent être trouvés dans [Bunni, 2003].

Résumé : "Those involved in construction have to cope with so much learning in their own discipline that they shun further involvement in subjects such as insurance and law which in themselves are so deeply and intensely complex. However, insurance and law are interwoven in the basic procedures used in the construction industry for undertaking work, be they design, construction, supervision or operation, or any combination of them. This thoroughly revised edition of Nael Bunni's successful book, formerly called Insurance in Construction, provides information on risk, construction law and construction insurance for those involved with all aspects of construction. The chapters on risk have been expanded to include recent developments in the area and provide further examples of events which could occur on what can be viewed as the most risky human work activity, namely construction. New chapters are also added to deal with the insurance clauses of the many new standard forms of contract published in recent years, including FIDIC's new suite of contracts published in September 1999, ICE's seventh edition of the civil engineering standard form of contract, and ICE's second edition of the design/build form."

Conclusion : Intéressant pour le contexte ; moins utile pour l'aspect quantitatif. Utile pour la revue de littérature.

6.4 Builder's risk insurance

Article wiki :

- Builder's risk insurance is a special type of property insurance which indemnifies against damage to buildings while they are under construction.[1] Builder's risk insurance is "coverage that protects a person's or organization's insurable interest in materials, fixtures and/or equipment being used in the construction or renovation of a building or structure should those items sustain physical loss or damage from a covered cause."[2]

- Necessity : Buildings are subject to many different risks while under construction. They may catch fire, be damaged by high winds, or fall victim to other force majeure. A principle of common law is that any new construction or other improvement to land becomes property of the owner of the land - the title holder - once there has been an "improvement" to the owner's site. Builder's risk insurance indemnifies against some of these losses.

- Coverage : Builder's risk covers perils such as fire, wind, theft and vandalism and many more. It typically does not cover perils such as earthquake, flood or hurricane damage unless the policy has been specifically endorsed to do so.[3] However, earthquake riders can be very economical, depending on where your project is located and should be considered. These policies also do not cover accidents and injuries at the workplace.[4] and is intended to terminate when the work has been completed and the property is ready for use or occupancy. If you are going to properly setup your policy, coverage should be effective prior to when the materials are delivered to the job site. Coverage ends upon the earlier of closing of the sale, occupancy or the policy expiration date. After builder risk coverage expires, due to sale or occupancy, the new owner should take out permanent property insurance on the building such as a home owner's policy or a commercial property policy. Insurance costs generally run between one and four percent of the construction cost, depending upon the type of insurance purchased and exclusions from coverage.[5]

- Who buys builder's risk insurance? :Coverage can be purchased by the property owner or general contractor. Builder's risk coverage may be necessary to show proof of insurance to comply with local city, county, and state building codes and is often required as a condition to many contracts. Many architects believe that it is the property owner who should have the builder's risk policy, because they have already paid for the improvements to their land, and if the general contractor receives the funds directly from a claim, theoretically, he/she could abscond with that benefit. It is far safer for the property owner to obtain the builder's risk policy, because they already own the building, even while it is under construction. If something happens to the under-construction project, then they should be the beneficiary and control how it is spent. Yes, the general contractor ends up receiving the funds in the end, to rebuild damage, but this method gives the control of the insurance benefit to the owner.

6.5 Assurance construction et actuariat

Dans [Cossette et al., 2018], nous avons fixé notre attention sur l'assurance construction pour les projets de grande envergure impliquant des structures en CLT

Contributions à la recherche en actuariat en assurance construction :

- Aucune contribution de recherche sur la tarification des polices d'assurance impliquant des produits CLT dans la littérature actuarielle (à ce jour)
- Aucune contribution de recherche spécifiquement sur la tarification de l'assurance construction dans la littérature actuarielle (à ce jour)
- Exceptions = Thèses MSc en France :
  - [Lavarny, 2018]
  - [Nataf, 2014]
  - Voir : http://www.ressources-actuarielles.net/

Contributions à la recherche en génie civil, ingénierie, etc. liées au CLT :

- Plusieurs articles se concentrent sur la performance des structures en CLT par rapport au risque d'incendie
- Les coûts de remplacement (matériel) ou de responsabilité suite à un incendie ou à un autre type de catastrophe ne sont pas analysés
- À notre connaissance, aucune de ces études ne portait sur l'analyse des coûts de remplacements suite à sinistres survenant sur des chantiers de construction

Remarques de [Cossette et al., 2018]:

- Contrairement à l'assurance individuelle, le processus de tarification utilisé par les actuaires pour l'assurance construction n'est pas clairement connu
- Les actuaires utilisent à la fois des modèles actuariels et l'expertise de spécialistes (ingénieurs, architectes, etc.)
- Une caractéristique cruciale des modèles actuariels est la classe de construction ISO attribuée par le souscripteur

6.6 Insurance Service Office (ISO)

Dans les secteurs de l'assurance IARD des particuliers et des entreprises, l'ISO (*Insurance Service Office*) fournit les services suivants :

- Informations statistiques, actuarielles, de souscription et de réclamation
- Langage de la politique et informations sur des emplacements spécifiques
- Outils d'identification des fraudes et services techniques

Désormais, l'ISO fait partie de Verisk : https://www.verisk.com/

L'ISO définit six classes de construction pour les bâtiments commerciaux :

- Construction Class 1 — Frame
- Construction Class 2 — Joisted masonry
- Construction Class 3 — Noncombustible
- Construction Class 4 — Masonry noncombustible
- Construction Class 5 — Modified fire resistive
- Construction Class 6 — Fire resistive

Caractéristiques ($\underline{y}$) dans les modèles actuariels pour l'assurance construction :

- Situation géographique, distance des services d'incendie, etc.
- Caractéristique importante (en particulier pour les structures CLT): classe de construction

Le calcul de la prime pour un chantier de construction en bois lamellé-croisé est établi par prédiction des coûts que ce dernier occasionnerait en cas de sinistre, et que le modèle prédit à partir des valeurs et modalités des variables explicatives.

Parmi les variables en question, les assureurs incorporent une (ou plusieurs) caractérisant les types de matériaux utilisés dans cette construction. Cette variable est catégorique, et l'on doit choisir des classes pour celle-ci qui regrouperaient les matériaux les plus homogènes en termes de risque. Selon les renseignements recueillis auprès d'assureurs, la classification utilisée est celle établie par le Insurance Services Office (ISO) (voir le lien https://www.verisk.com/insurance/capabilities/underwriting/commercial-property/construction-briefs/), et est présentée comme suit:

1. Résistant au feu

   Type de construction dans lequel la charpente, les murs porteurs, les planchers et le toit sont en maçonnerie ou en matériaux résistant au feu. La durée de résistance au feu doit être d'au moins 2 heures pour les planchers et les murs porteurs extérieurs, et d'une heure pour le toit. Aucun acier non protégé dans les murs ou le toit.

2. Maçonnerie - incombustible

   Type de construction dans lequel les murs sont en maçonnerie ou en matériaux ayant une durée de résistance au feu d'au moins deux heures, et dans lequel les planchers, le toit et leurs éléments porteurs sont en matériaux incombustibles.

3. Incombustible

   Type de construction dans lequel les murs, les planchers, le toit et les éléments porteurs sont en matériaux incombustibles (incluant les constructions en acier sur acier) et dont l'isolation est de fibre minérale.

4. Maçonnerie

   Type de construction dans lequel les murs sont en maçonnerie ou en matériaux ayant une durée de résistance au feu d'au moins une heure, et dans lequel les planchers et le toit sont en matériaux combustibles. Font également partie de cette classe la construction ordinaire et la construction en gros bois d'œuvre.

5. Brique sur bois

   Type de construction dans lequel les murs sont en matériaux combustibles revêtus, à l'extérieur, d'un parement de maçonnerie d'au moins 100 mm (4 pouces), et où les planchers et le toit sont en matériaux combustibles.

6. Bois

   Type de construction dans lequel les murs extérieurs sont en matériaux combustibles ou incombustibles autres que Brique sur bois et où les planchers et le toit sont de construction combustible.

Cette classification est principalement établie en fonction de la gravité des pertes pouvant être causées par un incendie. Elle est un peu similaire à celle figurant dans le International Building Code [International Code Council, 2015].

Le bois lamellé-croisé, étant du gros bois d'œuvre, est classé chez les assureurs consultés en 4-ième catégorie. Selon eux, celle-ci est la meilleure en termes de risque d'incendie pour les bâtiments ayant des planchers et des toits en matériaux combustibles.

6.7 Construction Coverage Mai 2021

Site : www.constructioncoverage.com/builders-risk-insurance

Remarque : le site contient des informations intéressantes, pour nous aider à comprendre

Builders risk insurance (also known as course of construction insurance) covers buildings and other structures while they are under construction.

6.7.1 What is Builders Risk Insurance?

Builders risk insurance, or course of construction insurance, is insurance coverage for buildings and other structures while they are under construction.

Builders risk policies always list specific types of property that they cover, which will usually include buildings and structures, fencing, temporary structures, foundations, piping, and more. Policies also specify particular causes of loss that the coverage protects against, typically including fire, extreme weather, vandalism, and theft. Most insurers also allow customers to add additional coverage for different types of property, causes of loss, and expenses by adding coverage extensions to the policy.

Builders risk policies are designed to cover only buildings and property under construction, so coverage usually begins when a construction project starts and terminates shortly after the project's completion or once the building becomes operational.

6.7.2 What Does Builders Risk Insurance Cover?

Builders risk insurance coverage can be most easily understood by looking at several components of the policy, which are (1) the covered property, (2) the covered causes of loss, and (3) the available policy extensions. Let's take a look at each.

Covered Property
Builders risk insurance covers damage to a property while it is under construction. Builders risk insurance policies often can include coverage for the following types of property at the construction site:
Buildings and structures Foundations Fixtures Machinery Underground piping
Electrical work and wiring Temporary structures Building materials Construction signs

Some other types of property may be covered under your builders risk insurance policy; however, you may have to add additional coverage with policy extensions (discussed below). Most standard policies will only cover the primary structure and items listed above by default. Covered Causes of Loss

In addition to the types of property covered, builders risk policies will always specify covered "causes of loss," identifying the specific events that qualify as coverable. Standard covered causes of loss include:

Fire Lightning Explosion Windstorm Hail Smoke
Aircraft or vehicle collision Riot or civil commotion Sprinkler leakage Vandalism Theft

Similar to covered types of property, insurance companies will usually give you the option to extend your policy to cover additional causes of loss, which might include falling objects, weight of snow, ice, sleet, or water damage, to name a few. It will also usually be possible to extend your coverage to account for any cause of loss that isn't explicitly excluded or limited in the extended policy terms, though that would cost much more than the standard policy. Additional Coverage Extensions

Builders risk insurers usually offer additional coverage options to extend coverage of the primary policy. Usually when there is an event that triggers your coverage, there are some additional costs that fall

outside of the standard coverage. Things like debris and pollutant cleanup, re-architect/engineering expenses, and labor expenses may be necessary and costly, so insurers will allow you to cover costs like these with additional coverage options.

Interestingly, many insurers structure their policy options very differently. While some insurers will offer a given policy feature in their standard builders risk policy, others might require the buyer to add that feature as a policy extension. And other insurers may only include that feature as part of a separate policy. Some insurers may not offer the coverage at all. Most of the additional coverage that we cover here will be offered by the majority of insurers in one form or another, usually as an extension to the base builders risk policy.

Some of the most common and useful optional coverage extensions include:
Property of others – The majority of builders risk insurance policies will not cover supplies or equipment that belong to others unless the owner is listed as an "additional insured" on the policy. Some insurance providers will offer this coverage as a policy extension. Many providers, however, most will only sell this coverage in a separate tools and equipment insurance policy. Trees, shrubs, sod, and plants – This policy extension adds coverage to plants on and around the property if they are damaged or destroyed in covered incidents. Almost all insurers will offer this as a coverage extension. Debris removal – This may come standard or as a policy extension depending on the insurer, but all insurers will offer this coverage. Debris removal coverage covers the cost of clearing and disposing of the debris and materials from a covered loss, which can often be a massive expense. Some insurers will also cover demolition costs if remaining parts of a damage structure must be torn down. Pollutant cleanup and removal – Sometimes a covered loss can result in the spillage of harmful pollutants on the jobsite or in the surrounding area. In this case, the party responsible for the spill must clean up the pollutants and possibly face legal penalties. A policy extension for pollutant cleanup will help cover these costs. This coverage is almost always presented as an optional extension, but some providers like The Hartford offer this and debris removal with their standard builders risk coverage. Electronic data and project documents – If any electronic data, files, or physical project documents are damaged in a covered loss, this policy extension will help cover the cost of restoring and replacing the documents and information, which can include costly amounts of research. Most insurers will provide optional coverage for this, and some will even include it in their base policy. Law / local ordinance changes – If a law or local ordinance changes during the construction project, this policy protection will cover the added costs of complying with the new laws, plus the costs of any delays that the new compliance adds to the project. This is frequently covered in the base builders risk policy but sometimes only sold as an extension. Replacement cost valuation – Sometimes, it will be standard practice for the insurer to provide replacement cost value for your materials and property that are damaged in a covered loss, rather than fair market or book value; however, this depends on the details of the specific policy. Often, coverage to receive replacement value will come as a separate addition to the policy. Profit coverage – Some insurers, like The Hartford, offer policy extensions that will actually cover the policyholder's profits for the project, based on profit assumptions from the job estimate. This is usually an available option with most insurers, if it isn't standard. Preservation of property – In an instance where covered property is being removed from the covered construction project location in order to prevent a potential covered loss or following a covered loss, that property will continue to be covered by this insurance policy if this extension is added. Fire department service charges – When the fire department is called, sometimes there is an associated fee due on behalf of the property or project owner. If the call to the fire department was for a covered incident, then this additional coverage will cover at least a portion of that cost. Labor expenses – Some policies will cover the additional labor costs that result from a covered loss; others will offer that coverage as an optional extension. Almost all insurers will offer this form of coverage. Re-architecture / engineering expenses – Businesses can add additional coverage to pay for the cost of architects and engineers following a covered loss. Sometimes, these types of expenses are referred to as "soft costs". Most insurers offer this. Contract delay / incompletion penalty coverage – Some contracts between owner and contractor will include financial penalties if the project is delayed or left incomplete. If a covered event causes a project to be left unfinished or delayed, this policy extension can cover those expenses. Expedited service expenses – If your business is forced to expedite shipping, staffing, or other aspects of the business to meet a deadline following a covered event, this coverage will pay for any expenses incurred to expedite construction. Modular unit coverage – For

contractors or businesses that use offsite modular units to store materials and equipment, this coverage means the units and equipment would be covered after a covered loss. Equipment testing – If a loss occurs during mechanical, pneumatic, electrical, or hydrostatic testing, this extension will cover the cost of the loss. This covers equipment such as A/C units, power generators, pressure vessels, boilers, production equipment, and more. This type of coverage is not as common as some others. Cost escalation protection – This protects the policyholder from any major increases in cost of materials and services that occur during the course of the project. If unforeseen economic changes lead to a drastic change in cost for certain materials, this policy extension covers that cost. Only a handful of insurers will actually offer this type of coverage as an option.

As we've pointed out, these additional coverage options may vary depending on the broker or insurer that the contractor or builder chooses. Not all insurers will offer the same coverage options. Furthermore, there are likely additional coverage options that we did not discuss here. Speak with potential insurance providers about the additional coverage extensions they offer to see whether any are applicable and worthwhile for your construction project. What Is Not Covered by Builders Risk Insurance?

Because builders risk insurance policies are designed specifically to cover structures under construction and some related items, builders risk policies leave a significant amount of the construction project unprotected. It is important to understand the items and types of incidents that fall outside of the scope of the builders risk policy so owners, contractors, and builders can appropriately manage their risk with other insurance policies that fill their gaps in coverage.

This list includes what's not typically covered by a builders risk insurance policy, but should be insured during most commercial and residential construction projects under a different type of policy. What's not typically covered by builders risk insurance
Injuries – Builders risk insurance policies do not provide liability coverage for injuries or damage caused by the insured during the construction project. For that type of coverage, separate liability insurance policies exist for contractors and construction companies. Vehicles – Vehicles used for the construction project are not typically covered under a builders risk insurance policy either, even when they are being driven to and from the job site. Commercial auto insurance policies are designed to cover vehicles owned by the contractor or construction company. Workers' compensation – If an employee is injured during the course of a construction project, sometimes the employer will be responsible for their missed wages, medical expenses, and other similar expenses. Workers' compensation insurance covers these costs for the employing company or contractor after covered incidents. Before and after construction – Builders risk insurance is only in effect during construction. Anything that happens outside of the window of construction (during normal operations) will not be covered under builders risk policies. Property owners should look to property insurance policies—like homeowners insurance or commercial property insurance—to protect themselves against any damages once construction is completed. Legal – Most insurance policies will not cover issues caused by a contractor who fails to adhere to standards and regulations of their trade. In order to protect against this issue, project owners should seek contractors who carry license bonds. There are also several other types of construction bonds that exist to ensure that contractors and business deliver on their contractual agreements throughout the construction project. Tools and equipment – One of the most common misconceptions is that the builders risk policy will cover the tools and equipment used on the project. This is not the case. Tool and equipment insurance policies are actually sold separately, though a handful of insurers will offer extensions to their builders risk policies to cover tools and equipment.

In addition to those areas of the project that are not covered, builders risk insurance policies do not cover certain excluded events, which are always defined in the policy paperwork. Every policy will come with a list of exclusions, or events for which the insurer is not responsible for covering damages. Most often, policies will exclude the following items. Builders risk exclusions
Law / ordinance compliance expenses – If you experience a covered loss, and are then forced to comply with some localized ordinances or laws during construction, most policies will not cover the cost of any special measures that need to be taken to comply with these laws. Earth movement – Coverage under builders risk will exclude damages from earthquakes, landslides, mine subsidence, sinkhole collapse, or

volcanic eruption and any related events. Government seizure or action – If for any extreme reason, the government seizes or destroys property, it will be excluded. This type of incident is usually only ever going to occur in the most extreme cases of war or extreme political uprising. Nuclear hazard – Most insurers will explicitly exclude coverage for damages caused by a nuclear reaction, radiation, or contamination. Utility services – If the property experiences a loss of power, water, internet, phone, or other utility service, insurance providers will typically not cover any associated costs. War and military action – In the unlikely case of damages caused by warlike activities on or around the property—including revolution, insurrection, rebellion, usurped power, or government action taken to respond—coverage will not be provided by the majority of insurance companies. Water / flooding – Losses caused by water will generally not be covered by insurance providers. Types of water-related events that fall into this exclusion include flooding, sewer or drain overflow, and mudslides. Fungus, bacteria, rot – Any damages caused by fungus, bacteria, wet rot, or dry rot will be excluded from coverage under a standard builders risk insurance policy.

One note is that for almost all of these exclusions, insurance companies usually sell policy extensions or separate policies that add or extend relevant coverage. If you are concerned about any of the items listed above, it's worth discussing your options with the insurance provider you are considering. Such policy extensions vary widely in cost.

Related Insurance Policies
When first learning about builders risk, many buyers tend to believe it is unnecessary because their existing insurance policies will still protect them during construction projects. However, other insurance policies usually will not protect policyholder property or buildings that are damaged during the course of a construction project. Thus, it's important to understand what your existing insurance policies do and do not cover. Builders Risk vs. Homeowners Insurance
What is the difference between builders risk and homeowners insurance? Homeowners insurance is designed to protect homeowners from the cost of damages to their home and provide liability protection after an injury on their property.
While this sounds like it would encompass the same coverage that builders risk provides, homeowners insurance will not apply during a construction project on the covered home. In fact, damage while a property is under construction is listed as an exclusion on most homeowners insurance and landlord insurance for rental property, as you can see in the "Section I – Exclusions" section (item B.3.c) in this sample homeowners insurance policy from the Insurance Information Institute. On the other hand, builders risk insurance policies only cover damages caused during the course of the construction project.
Builders Risk vs. Contractors All Risk Insurance
Contractors all risk insurance only applies to policies written outside of the United States, but it is merely a hybrid policy that combines the coverage of both builders risk and contractor general liability insurance policies. These all risk policies also usually offer various policy extension options. These non-traditional policies can be useful for contractors operating outside of the United States. Builders Risk vs. Inland Marine Insurance
Inland marine insurance is intended to cover property at any location, whether it is in possession of its owner, in transit, or in the custody of another person. It is often used in construction by contractors to protect their tools and equipment, but it is common for many professionals who use and travel with expensive property or equipment, such as photographers and healthcare professionals.
Some insurers actually classify their builders risk policy as a form of inland marine insurance, even though the property being insured (the building) remains in one location. Most of the time, however, builders risk and inland marine policies are considered different forms of insurance with different purposes.
To complicate things further, some insurance companies will offer policy extensions to their builders risk insurance that cover the contractors' tools and equipment. In this case, a separate inland marine policy is not necessary for the construction project, but this policy extension is not available with every insurance provider.
To summarize, builders risk insurance covers the building while it is under construction, and inland marine insurance covers the contractors' equipment and tools (whether they are at the jobsite or in transit). Builders Risk vs. Property Insurance

Commercial property insurance covers all types of commercial property (buildings, inventory, furniture, etc.) against covered causes of loss, such as fire, theft and natural disaster. However, when businesses renovate or build new buildings on their property, the additions are not covered by standard commercial property insurance policies while they are being built.

Builders risk is actually a form of property insurance, but it is sold separate from standard commercial property management insurance policies because its protections only apply to the property when it is under or construction or being built. Even if a business already has property insurance covering their building, they will need to purchase a separate builders risk policy to cover that same building during a renovation or construction project. Builders Risk vs. General Liability

General liability insurance, in construction, protects policyholders (usually contractors or construction companies), from third-party liability. An example would be if a third party alleges that the contractor caused an accident or injury. Most contractors or construction businesses carry general liability insurance.

A contractor general liability policy may actually cover damages to an in-progress structure if those damages were caused by a subcontractor that the policyholder hired. But all other situations where damages could occur to the in-progress structure (fire, weather, theft, vandalism) would not be covered by the general liability policy.

Both of these policies will usually be necessary for any large contracted project in the United States. Those outside of the U.S. might consider a "builders all risk" or "contract works" insurance policy, which spans both areas of coverage. Builders Risk vs. Installation Floater

Installation floaters are policy extensions for inland marine insurance policies that add coverage to equipment and property that is to be installed into a building or structure. Typically, the inland marine insurance policy will cover the contractor's property, like tools, generators, and other equipment. Addition of an installation floater extends coverage to property that doesn't belong to the contractor, but is to be installed during construction, for example, air conditioning units, water heaters, septic tanks, or roofing materials.

If a contractor is only installing something like an air conditioning unit or a hot water heater, builders risk insurance is much more coverage than necessary for the job. Adding an installation floater to an existing inland marine tool and equipment insurance policy will be the cheaper and more appropriate option to cover smaller projects like these. Builders Risk vs. Vacant Dwelling Coverage

Vacant dwelling insurance policies are simple policies that protect against damage and theft to a home when it is vacant for an extended period of time, usually greater than 60 days. These policies are usually meant for homeowners who either cannot move into their new property yet, or landlords who own property that doesn't currently have tenants. And while the home will certainly be vacant during a large construction project or remodel, the vacant dwelling policies will not cover the property during construction. Properties under construction will actually be excluded from coverage in the terms of the policies. Builders Risk vs. OCIP

Builders risk insurance is actually a very common component of owner controlled insurance programs (OCIP insurance); however, they are two very different methods of insuring construction projects.

OCIPs combine workers compensation, builders risk, commercial general liability, excess liability, and other insurance policies into a single insurance program that is purchased by the owner and set up for contractors enroll in. Contractors who enroll gain the coverage of the entire policy.

Owner controlled insurance programs can provide nice cost savings to project sponsors through the bulk purchase of insurance for the entire project. An OCIP could be a great option for owners with large, or many similar, projects. Also, check out our section on OCIP vs. CCIP to learn more about how owner-controlled insurance programs differ from contractor-controlled insurance programs.

How Much Does Builders Risk Insurance Cost?

The average builders risk insurance policy costs approximately 1–5

These ranges come from a number of sources, including insurance agencies, expert blogs, and interviews with construction professionals. Of course, the quoted percentages are just estimates, and broad ones at that. A project that the insurer deems complex and "highly risky" could require higher base premiums, while a simple, low-risk project would likely fall at the lower end of the estimated range.

Factors that Determine the Cost of Builders Risk Insurance

Several factors influence the price of a builders risk policy. Unfortunately, there is no exact formula to determine the exact cost for your project. On a project-by-project basis, insurance company underwriters take in as much relevant information as they can and calculate appropriate policy premiums. Of course, each insurer has their own rules about how different factors affect the final policy price, but most underwriters consider the following information:
Type of project – The insurer needs to know if the project is a new building construction or a renovation/remodel. Coverage for remodels and renovations can be more pricey than for new building construction because of the risk that the existing structure could be damaged. Replacing an existing structure would be much more expensive for the insurance company, so they require higher premiums to balance their risk. However, most insurers allow you to forgo coverage of the existing structure during a renovation, in order to reduce the cost of the policy. Type of building – The type of building—an apartment building, hotel, single-family residence, office building, etc.—will be a major determining factor with regard to policy price. Generally speaking, large, commercial projects are the most expensive to insure even on a percentage basis. Square footage – Applications will usually ask for the square footage of the project. Usually, more square footage equates to larger premiums, though other factors will influence the price of the policy more than this. Material / build quality – The types of materials used in the construction project could have an effect on policy cost for a couple of reasons. First, if the materials are exotic, unconventional, extremely high quality, or difficult to replace, they will cost more to insure. A separate consideration regarding the materials is whether they are prone to incident. For example, wood frames are highly flammable, and thus, more expensive to insure than other more fire resistant materials. Estimated cost of the project – Because the cost of a policy is roughly proportional to the cost of the project, it makes sense that more costly projects require more costly insurance. However, the project may become less expensive per square foot as the total cost of the project goes up. But that isn't necessarily true for all projects. Location – The location of the project plays a big role in determining the cost of coverage. If the area frequently has intense weather, high risk of catastrophe, or high levels of crime, it may cost more to insure the build. Additionally, the proximity to fire stations and fire hydrants is considered.
In addition to the details of the project that the underwriter will consider, there are details about the policy that will also influence the monthly premium. Here are the major policy factors impacting price that the purchaser can control:
Covered parties – The identity of the individuals and businesses covered by the policy is a factor that underwriters consider when determining price. Including subcontractors on the policy who have previously filed for bankruptcy or who have a poor track record of safety could increase the cost of the policy. Consider requiring subcontractors to carry their own insurance policies to minimize this possibility. Policy extensions – As we discussed above, buyers can extend coverage of their policy by purchasing any number of the policy extensions offered by the insurer. These extensions can add coverage for additional causes of loss or additional types of property, but they also add to the monthly premiums. Coverage limits – Coverage limits are how the insurance companies will cap the amount they have to pay out after a covered loss. By increasing the cost of the policy, policyholders can increase the limit that the insurer will pay out for a covered loss. Deductible – The deductible is the amount that the insured party must pay toward damages caused by a covered loss before the insurance company is responsible for payment. If the policyholder agrees to pay a higher deductible, the premium will be lowered. A lower deductible means a higher premium. Duration of coverage – Typically coverage is available in 6 or 12 month time periods. It is possible to extend the length of coverage, but doing so will also likely increase the cost of the policy. The longer the insurer provides coverage to a project, the more likely a loss becomes.

7 Actuariat et péril incendie

7.1 Contributions actuarielles

En général, les actuaires modélisent les coûts observés des sinistres liés au péril incendie.

Les actuaires ont aussi proposés des approches pour calculer des primes pour les contrats de réassurance pour le péril incendie.

Structure de la section:

- Le titre de la sous-section est le titre de l'article (ou du document).
- On a reproduit le résumé et fait de brefs commentaires.

7.2 The probability distribution of fire loss amount

Dans cet article, l'auteur examine la modélise des coûts en sinistre pour le péril incendie : [Shpilberg, 1977].

Résumé : "Theoretical distributions frequently used to model fire loss amount are discussed. The problem of selecting models solely on the basis of statistics is addressed. Use of probabilistic arguments applied in Reliability theory to infer the type of probability distribution, is explored. The concept of failure rate of a fire is discussed and used to explore implications of the Pareto and Lognormal models as to the fire growth phenomenon. It is concluded that probabilistic arguments, regarding the nature of the fire growth process can aid analysts in their choice of an appropriate model for the probability distribution of fire loss amount."

7.3 Statistical models of claim distributions in fire insurance

Même s'il n'est pas récent, cet article me semble intéressant : [Benckert and Jung, 1974].

L'analyse porte spécifiquement sur le risque incendie.

Résumé : "The authors have studied the combined data on claims in fire insurance of dwelling houses reported 1958-1969 by Swedish fire insurance companies The claims were cleared of deductibles and adjusted according to a suitable index Only losses above the largest deductible (in real value) applied during the observation period were included. The material contains four different classes according to the fire resistibility of the building construction For international comparisons, the pure classes B1 ("stone" dwellings) and B4 (wooden houses) are of interest The distribution of the claims could be well approximated by the log-normal distribution in B1and by the Pareto distribution in B4 An equally good or better fit was obtained by assuming the original loss, reported or not, being distributed according to these distributions and applying the distributions, conditioned by the loss being larger than the deductible in both cases the distribution parameters are functions of the insurance amount in such a way, that the mean value of the loss is described as a power of this amount."

7.4 Statistical models of claim distributions in fire insurance

Résumé : "[Benckert and Jung, 1974] : The authors have studied the combined data on claims in fire insurance of dwelling houses reported 1958-1969 by Swedish fire insurance companies The claims were cleared of deductibles and adjusted according to a suitable index Only losses above the largest deductible (in real value) applied during the observation period were included. The material contains four different classes according to the fire resistibility of the building construction For international comparisons, the pure classes B1 (“stone” dwellings) and B4 (wooden houses) are of interest The distribution of the claims could be well approximated by the log-normal distribution in B1and by the Pareto distribution in B4 An equally good or better fit was obtained by assuming the original loss, reported or not, being distributed according to these distributions and applying the distributions, conditioned by the loss being larger than the deductible in both cases the distribution parameters are functions of the insurance amount in such a way, that the mean value of the loss is described as a power of this amount."

7.5 Deductibles in industrial fire insurance

Cet article porte sur l'assurance incendie industriel : [Strauss, 1975].

Il est fréquemment cité.

Résumé : "In recent times, the subject of deductibles in Industrial Fire insurance has gained significance to an increasing extent. In fact, up to a short time ago it was by no means common to apply deductibles in Industrial Fire insurance in Europe. The situation is entirely different in the USA where deductibles are the usual thing and are even obligatory with individual risk categories (e.g. petroleum refineries), hazards (e.g. explosion), or special types of companies (e.g. factory mutuals). Today, however, there is a definite increase in the demand for deductibles in Industrial Fire insurance in Europe, too. This trend may be explained by the fact that in order to reorganize their business successfully, insurers have been forced to increase their premiums by a considerable amount. It seems to be an unwritten law that when premiums in general are increased considerably, the point will some time or other be reached when the insured do not accept any further premium increases. Thus, even if such increases are completely justified in a view of claims experience, the insured will demand that premiums are reduced either by the insurer granting rebates for appropriate loss prevention measures or by the introduction of deductibles. In the USA, for example, such a situation arose around 1960 when considerable premium increases very quickly led to the introduction of substantial deductibles in Industrial business. In some European countries we are currently experiencing a similar development."

7.6 Modelling fire contagion with application in fire farm insurance

Article récent de JP : [Boucher et al., 2021].

À mon avis, il y a une bonne piste. Voir les travaux par les ingénieurs, p.ex. [Rychlik and Rydén, 2006], etc.

Résumé : "In a farm, a fire that starts in any structure can spread to all other structures of that same farm, to barns, granaries, silos, etc.. Intuitively, we then expect that a farm with more structures will be more at risk of fire propagation than a smaller one. From an actuarial perspective, as the total premium for farm insurance is the sum of premiums of each structure of that farm, it is therefore necessary to propose a way to compute each premium by considering the risk of fire propagation. Based on the distances between structures on the same farm, we propose a new pricing approach that considers fire propagation. The proposed model makes it possible to analytically compute the probability of fire propagation as a function of the fire origin. This can in turn be used to price all individual structures of any given farm. A practical application of the model based on insurance data and satellite images is given."

7.7 Property graphs–A statistical model for fire and explosion losses based on graph theory

Article super intéressant : [Parodi and Watson, 2019].

Résumé : " It is rare that the severity loss distribution for a specific line of business can be derived from first principles. One such example is the use of generalised Pareto distribution for losses above a large threshold (or more accurately: asymptotically), which is dictated by extreme value theory. Most popular distributions, such as the lognormal distribution or the Maxwell-Boltzmann-Bose-Einstein-Fermi-Dirac (MBBEFD), are convenient heuristics with no underlying theory to back them. This paper presents a way to derive a severity distribution for property losses based on modelling a property as a weighted graph, that is, a collection of nodes and weighted arcs connecting these nodes. Each node v (to which a value can also be assigned) corresponds to a room or a unit of the property where a fire can occur, while an arc (v, v'; p) between vertices v and v' signals that the probability of the fire propagating from v to v' is p. The paper presents two simple models for fire propagation (the random graph approach and the random time approach) and a model for explosion risk that allow one to calculate the loss distribution for a given property from first principles. The MBBEFD model is shown to be a good approximation for the simulated distribution of losses based on property graphs for both the random graph and the random time approach."

Lien à faire avec l'article de JP [Boucher et al., 2021].

7.8 On fire exposure rating and the impact of the risk profile type

Article intéressant : [Riegel et al., 2010].

Résumé : "We analyze fire exposure rating for three types of risk profiles: policy profiles, top location profiles and location profiles. Location profiles offer more detailed information than top location profiles, which in turn are better than policy profiles. We prove criteria to ensure that a better quality of risk profile leads to a lower price. These criteria are discussed with respect to standard exposure rating and an alternative method called â€˜burning cost-adjusted exposure ratingâ€™, where the loss ratio is adjusted by means of the burning cost of a low reference layer. Further, we introduce a family of analytic exposure curves, the so-called EP exposure curves. These curves are useful for practical application, since the criteria given in this paper can be checked easily for exposure curves that can be approximated by EP exposure curves. This is of particular interest for discrete exposure curves. Finally, we apply the results to the MBBEFD exposure curves."

7.9 Tail risk in commercial property insurance

Article intéressant : [Biffis and Chavez, 2014]

Résumé : "We present some new evidence on the tail distribution of commercial property losses based on a recently constructed dataset on large commercial risks. The dataset is based on contributions from Lloyd's of London syndicates, and provides information on over three thousand claims occurred during the period 2000–2012, including detailed information on exposures. We use occupancy characteristics to compare the tail risk profiles of different commercial property exposures, and find evidence of substantial heterogeneity in tail behavior. The results demonstrate the benefits of aggregating granular information on both claims and exposures from different data sources, and provide warning against the use of reserving and capital modeling approaches that are not robust to heavy tails"

7.10 A generalised property exposure rating framework that incorporates scale-independent losses and maximum possible loss uncertainty

Article très intéressant: [Parodi, 2020].

Résumé : It is rare that the severity loss distribution for a specific line of business can be derived from first principles. One such example is the use of generalised Pareto distribution for losses above a large threshold (or more accurately: asymptotically), which is dictated by extreme value theory. Most popular distributions, such as the lognormal distribution or the Maxwell-Boltzmann-Bose-Einstein-Fermi-Dirac (MBBEFD), are convenient heuristics with no underlying theory to back them. This paper presents a way to derive a severity distribution for property losses based on modelling a property as a weighted graph, that is, a collection of nodes and weighted arcs connecting these nodes. Each node (to which a value can also be assigned) corresponds to a room or a unit of the property where a fire can occur, while an arc between vertices v and v' signals that the probability of the fire propagating from v to v' is p. The paper presents two simple models for fire propagation (the random graph approach and the random time approach) and a model for explosion risk that allow one to calculate the loss distribution for a given property from first principles. The MBBEFD model is shown to be a good approximation for the simulated distribution of losses based on property graphs for both the random graph and the random time approach.

7.11 desmedt2012experience

Article de JF Wahlin et collègues de la SCOR : [Desmedt et al., 2012].

Comparaison entre "Experience ratin" et "exposure rating"

Résumé : "Experience and exposure rating are traditionally considered to be independent but complementary methods for pricing property per risk excess of loss reinsurance. Strengths and limitations of these techniques are well-known. In practice, both methods often lead to quite different prices. In this paper we show that limitations of traditional experience rating can be overcome by taking into account historical profile information by means of exposure curves. For pricing unused or rarely used capacity, we propose to use exposure rating, calibrated on the experience rate of a working layer. We compare the method presented with more traditional methods based on the information which is generally available to the reinsurer.".

7.12 Economic Risk Capital and Reinsurance: an Extreme Value Theory's Application to Fire Claims of an Insurance Company

Cet article de 2001 me semble pertinent : [Corradin et al., 2002].

Les chercheurs viennent de LLN et travaillent dans la pratique.

Résumé : "The viability of an insurance company depends critically on the size and frequency of large claims. An accurate modelling of the distribution of large claims contributes to correct pricing's and reserving's decisions while maintaining, at an acceptable level, the unexpected fluctuations in the results through reinsurance. We provide a model for large losses and we extrapolate through a simulation a scenario based on separate estimation of loss frequency and loss severity according to extreme value theory, with particular reference to generalized Pareto approximations. We present an application to the fire claims of an insurance company. One conclusion is that the distribution of fire claims is long-tailed and an accurate exploratory data analysis is done to detect heavy tailed behavior and stability of parameters and statistics across different thresholds. We simulate the impact of a quota share and an excess of loss reinsurance structure on the distribution of total loss and on economic risk capital. We provide also a tool to price and investigate how different reinsurance programs can affect economic risk capital and explain the rationale of the choice of the optimal reinsurance programmes to smooth economic results."

8 Génie et péril incendie

8.1 Approche génie vs approche actuariat

Dans leurs travaux de recherche scientifiques, les ingénieurs examinent les aspects suivants :

- Temps de combustion de la structure ;
- Survie des occupants ;
- Respect du code du bâtiment ()
- ...

Dans leurs travaux de recherche scientifiques, les ingénieurs n'examinent pas (en général) les aspects suivants :

- Coûts de remplacement des structures ;
- Coûts de dommages aux structures ;
- ...

Structure de la section:

- Le titre de la sous-section est le titre de l'article (ou du document).
- On a reproduit le résumé et fait de brefs commentaires.

8.2 Probability and risk analysis

Il s'agit d'un ouvrage publié chez Srpinger, un équivalent du livre *Loss Models* [Klugman et al., 2012] pour les ingénieurs : [Rychlik and Rydén, 2006]

Il contient plusieurs exemples intéressants pour nous aider dans l'analyse du risque incendie, autant pour l'avènement d'un incendie que pour la gravité :

- Example 1.11 (Information on fires). Consider an initiation event A, fire ignition reported to a fire squad. After the squad has been alarmed and has done its duty at the place of accident, a form is completed where a lot of information about the fire can be found: type of alarm, type of building, number of staff involved, and much more."
- Example 2.7 (Fire ignition). Probabilities of ignitions have been studied intensively in fire-safety literature and formulae have been proposed for different types of buildings as well as different geographical locations.
- Etc.

Bref, nous pourrons y trouver des suggestions pour la recherche.

Résumé : "This book presents notions and ideas from the foundations of a statistical treatment of risks. Bayesian methods are frequently used in that area, hence a reasonable proportion of the presentation is devoted to such approaches. Modern statistical tools, namely Poisson regression, analysis of deviance, extreme-value theory and threshold methods are also used to identify and solve practical problems. The knowledge of such tools facilitates the understanding of the role of probability in risk analysis and proper use of outputs given by software packages. The book is written with a student in mind who has studied elementary undergraduate courses in engineering mathematics, perhaps including an introductory course in statistics. The text emphasizes an understanding of the theory and methods presented. Hence, comments are given verbally and an intuitive reasoning is frequent. This is not just another new textbook on elementary probability and statistics, but focuses strongly on applications within the field of risk and safety analysis."

8.3 A note on estimation of intensities of fire ignitions with incomplete data

Dans ([Rydén and Rychlik, 2006]), lea auteurs examinent le problème d'occurrence d'un incendie via un processus de Poisson.

Ils examinent le problème d'exposition : "**The proposed methodology is specifically useful in the case with small data sets or lack of information about the population at risk.**"

Résumé: "Occurrences of fire ignitions in a given region during a specified period of time are modelled as outcomes of a Poisson point process. The ignition frequency is considered a function of the total floor area of the building. Parameter estimates and their uncertainties are computed. Different criteria for model selection are used. The proposed methodology is specifically useful in the case with small data sets or lack of information about the population at risk."

8.4 Compartment fire risk analysis by advanced Monte Carlo simulation

Dans [Au et al., 2007], les auteurs proposent d'utiliser les méthodes de Monte Carlo pour analyser le comportement de structure (quelconque) exposé au risque incendie.

Résumé: "Quantitative fire risk analysis aims at providing an assessment of fire safety on a scientific basis and taking relevant uncertainties into account in a rational quantitative manner. Under a probabilistic approach, performance measures are formulated as multi-dimensional probability integrals, whose efficient computation is pivotal for practical implementation. Direct Monte Carlo method is a well-known technique, but it is not efficient for investigating rare failure events which are commonly encountered in engineering applications. A recently developed stochastic simulation approach called Subset Simulation is presented for quantitative fire risk analysis with a focus on the critical temperature in a compartment fire event. In the method, random samples leading to progressive failure are generated efficiently and they are used for computing probabilistic performance measures by statistical averaging. The random samples can also be used for probabilistic failure analysis, which yields information conditional on the occurrence of the failure event. A global approach is adopted for incorporating the uncertainties in the functionality of active fire measures into the fire risk analysis, where the failure probabilities can be obtained by a single simulation run rather than by multiple runs exhausting the possibilities in the associated event tree."

8.5 Dynamic modeling of fire spread in building

Le CRSNG a financé les travaux de cet article : [Cheng and Hadjisophocleous, 2011].

Les chercheurs travaillent à Carleton University.

Résumé : "Modeling fire spread in a building is a key factor of a fire risk analysis used for fire safety designs of large buildings. In this paper, a dynamic model of fire spread considering fire spread in both horizontal and vertical directions is described. The algorithms for simulating the fire spread process in buildings and calculating dynamic probability of fire spread for each compartment at each time step of simulation are proposed. The formulae used in calculating the input data for the dynamic fire spread model are derived. The dynamic fire spread model can easily be applied for any building including high-rise buildings. A detailed example of calculation of fire spread in a two-storey office building is described."

8.6 Fire risk analysis of a 6-storey residential building using CUrisk

Le CRSNG a financé les travaux de cet article : [Li et al., 2013].

Les chercheurs travaillent à Carleton University.

Résumé : "A quantitative fire risk analysis computer model CUrisk is being developed at Carleton University to evaluate the fire performance of buildings. For different fire scenarios, fire conditions in all the compartments of a building can be predicted by the Smoke Movement and Fire Growth submodels. CUrisk also considers fire spread from the compartment of fire origin to other compartments using the newly developed Fire Spread submodel. The results of these submodels as well as the outputs of the Occupant Response and Evacuation submodels are used by the Life Hazard and Economic Loss submodels to determine the consequences of each scenario in terms of expected number of deaths or injuries and fire losses. CUrisk takes into consideration the effect of different fire protection measures such as sprinkler systems, detectors and alarms and fire department actions. After analyzing all the possible fire scenarios, two final decision making parameters, the Expected Risk to Life and Fire Cost Expectation are calculated. A case-study using a six-storey residential building has been conducted using CUrisk and results are presented and analyzed in this paper."

8.7 The modeling of fire spread in buildings by Bayesian network

Le CRSNG a financé les travaux de cet article : [Cheng and Hadjisophocleous, 2009].

Les chercheurs travaillent à Carleton University.

Résumé : Fire spread modeling is very important to fire safety engineering and to insurance industries involved in fire risk–cost analysis of buildings. In this paper, the Bayesian network is introduced. The directed acyclic graph of a fire spread model is presented. When the fire ignition location is known, the fire spread model based on the Bayesian network from the compartment of fire origin to another compartment can be built, and the probability of fire spread can be calculated by making use of the joint probability distribution of the Bayesian network. A specific application for an office building is presented for a case without sprinkler and one with sprinkler installed.

8.8 Societal decision-making for optimal fire safety

Dans la thèse [Fischer, 2014], l'auteur examine le calcul de la prime en tenant des coûts en lien au péril incendie et tenant compte des coûts pour les mesures de réduction du péril incendie.

Le chapitre 4 me semble très pertinent : "Absolute risk assessment for societal decision support"

La thèse contient aussi des informations qui pourraient nous être utiles.
Résumé : "a"

8.9 A survey of 40,000 building fires in Switzerland

Cet article peut nous être utile et nous fournir des idées pour le projet (analyses, etc.) : [Fontana et al., 1999].

Résumé : "A survey of all building-fires in the canton of Berne for the period of 1986 to 1995 was performed by the ETH (Eidgenössische Technische Hochschule, Zürich) and the GVB (Gebäudeversicherung des Kantons Bern) to establish a statistical database for fire safety engineering. It contains data on fire loss to the building structure (not the contents) from nearly 40,000 fires reported to the GVB over that period and may provide valuable information for fire safety engineering."

8.10 Fire performance of timber structures under natural fire conditions

Autre article à lire : [Frangi and Fontana, 2005]

Résumé: " In recent years the use of wood as a building material has become popular, especially for dwellings. One of the preconditions for its use is adequate fire safety. Technical measures, especially sprinkler and smoke detection systems, well equipped fire brigades and a better knowledge in the area of structural fire design of timber structures allow the use of timber in a wider field of application. Full scale tests on wooden modular hotels were performed under natural fire conditions to look at the efficiency of different fire safety concepts. In a first series the efficiency of technical measures, especially fast response sprinkler systems, was studied. The second series showed the possibility and limits of structural fire safety measures. Special attention was given to the influence of combustible room surfaces on fire growth and fire spread inside and outside the room. The tests enlarged the experimental data for validation of natural fire simulations (temperatures, fire spread etc.) and for verifying the methods for the fire resistance calculation of wood constructions."

Mario Fontana est auteur du présent article [Frangi and Fontana, 2005] ainsi que des articles [Fontana et al., 1999], [Fischer et al., 2015], et [De Sanctis et al., 2014].

8.11 Combining engineering and data-driven approaches: Calibration of a generic fire risk model with data

Cet article est à lire : [Fischer et al., 2015].

À mon avis, cet article pourra nous être utile pour notre projet.

Fischer est aussi l'auteur de la thèse [Fischer, 2014].

Le contenu du chapitre 4 de la thèse [Fischer, 2014] de l'article [Fischer et al., 2015].

Résumé : "Two general approaches may be followed for the development of a fire risk model: statistical models based on observed fire losses can support simple cost-benefit studies but are usually not detailed enough for engineering decision-making. Engineering models, on the other hand, require many assumptions that may result in a biased risk assessment. In two related papers we show how engineering and data-driven modelling can be combined by developing generic risk models that are calibrated to statistical data on observed fire events. The focus of the present paper is on the calibration procedure. A framework is developed that is able to deal with data collection in non-homogeneous portfolios of buildings. Also incomplete data sets containing only little information on each fire event can be used for model calibration. To illustrate the capabilities of the proposed framework, it is applied to the calibration of a generic fire risk model for single family houses to Swiss insurance data. The example demonstrates that the bias in the risk estimation can be strongly reduced by model calibration."

8.12 Combining engineering and data-driven approaches: Development of a generic fire risk model facilitating calibration

Cet article est à lire : [De Sanctis et al., 2014].

À mon avis, cet article pourra nous être utile pour notre projet.

Un des auteurs est Fischer, aussi l'auteur de la thèse [Fischer, 2014].

Le contenu du chapitre 4 de la thèse [Fischer, 2014] de l'article [De Sanctis et al., 2014].
Résumé: "Fire risk models support decision making for engineering problems under the consistent consideration of the associated uncertainties. Empirical approaches can be used for cost-benefit studies when enough data about the decision problem are available. But often the empirical approaches are not detailed enough. Engineering risk models, on the other hand, may be detailed but typically involve assumptions that may result in a biased risk assessment and make a cost-benefit study problematic. In two related papers it is shown how engineering and data-driven modeling can be combined by developing a generic risk model that is calibrated to observed fire loss data. Generic risk models assess the risk of buildings based on specific risk indicators and support risk assessment at a portfolio level. After an introduction to the principles of generic risk assessment, the focus of the present paper is on the development of a generic fire risk model for single family houses as an example. The risk model considers the building characteristics of a single family house as well as the uncertainties associated with the fire spread in a building and the intervention of the fire brigade."

8.13 Building Fire Risk Analysis

À lire : [Meacham et al., 2016]

Résumé : Building Fire Risk Analysis provides insight into how to enhance the design, construction and management of our built environment. Fire safety, as a concept, branches into all manner of fields. It can affect a building's design and appearance, its capital and ongoing costs, its day-to-day functionality and above all the community or business it serves – in the event of a fire. Understanding risk is fundamental for consultants, approval organizations, Fire Brigades, insurers and regulators. Fire risk is embedded within codes and guidance – where decisions have been made about what is reasonable and practicable for buildings based on their size and use. This chapter explores what risk is and how it may be understood for future decision making throughout the fire safety industry. Risk herein is defined as the possibility of an unwanted outcome in an uncertain situation. Three key factors are: loss or harm of something; the event(s) that causes loss; and, the likelihood it will occur. The unwanted outcome generally affects life safety, property, business continuity, heritage, the environment, or a combination of these. The reality of our built environment, both now and in the future, is that unwanted outcomes are subject to a variety of active, passive and managerial systems which all contribute to improving safety and reducing risk. Risk assessment allows these systems to be fairly understood and the best decisions made to address the needs required.

Keywords: Fire Protection ; Fire Safety ; Fire Risk ; Fire Scenario ; Fault Tree Analysis

8.14 Principles of fire risk assessment in buildings

Lire le chapitre 3 (et d'autres chapitres) du livre suivant : [Yung, 2008].

Résumé: " This book arrives at just the right time to facilitate understanding of performance-based fire risk assessment in buildings - an integral part of the global shift in policy away from traditional prescriptive codes. Yung, an internationally recognised expert on the subject of fire risk assessment, introduces the basic principles and techniques that help the reader to understand the various methodologies that are currently in place or being proposed by different organisations. Through his illustration of basic principles and techniques he enables the reader to conduct their own fire risk assessments. He demonstrates how the probabilities of fire scenarios are assessed based on the probabilities of success and failure of fire protection measures that are in place. He also shows how the consequences of fire scenarios are assessed based on the intensity and speed of fire and smoke spread, the probability and speed of occupant response and evacuation, and the effectiveness and speed of fire department response and rescue efforts. Yung's clear and practical approach to this highly topical subject enables the reader to integrate the various tools available into a quantitative framework that can be used for decision making. He brings an invaluable resource to all those involved in fire engineering and risk assessment, including students, academics, building designers, fire protection engineers, structural engineers, regulators and risk analysts."

8.15 The economics of fire protection

Livre à lire : [Ramachandran, 2002].

L'auteur du livre [Ramachandran, 2002] est un spécialiste dans le domaine.

Titre du chapitre 11 du livre : "Fire insurance".

Extrait du premier paragraphe du chapitre 11 : "The object of this chapter is to briefly review the statistical problems involved in fire insurance and discuss the calculation of rebates in insurance premiums for deductibles and fire protection measures in industrial fire insurance. "

Selon cet auteur, "**The interaction between fire protection and insurance has not received sufficient attention in actuarial literature.**" (premier paragraphe du chapitre 11).

Dans le chapitre 11, il présente "sa" méthodolodgie pour modéliser les coûts liés au péril incendie et pour calculer une prime. Sa méthodologie a été appliquée par d'autres chercheurs.

Nombre de citations : 140 (en date du 2021-06-16).

Il est aussi auteur des contributions suivantes : [Ramachandran and Hall, 2016], [Ramachandran, 1980], [Ramachandran and Charters, 2011], etc.

Il faudrait les regarder.

Résumé : "This important new book, the first of its kind in the fire safety field, discusses the economic problems faced by decision-makers in the areas of fire safety and fire precautions. The author considers the theoretical aspects of cost-benefit analysis and other relevant economic problems with practical applications to fire protection systems. Clear examples are included to illustrate these techniques in action. The work covers:
* the performance and effectiveness of passive fire protection measures such as structural fire resistance and means of escape facilities, and active systems such as sprinklers and detectors
* the importance of educating for better understanding and implementation of fire prevention through publicity campaigns and fire brigade operations
* cost-benefit analysis of fire protection measures and their combinations, taking into account trade-offs between these measures.
The book is essential reading for consultants and academics in construction management, economics and fire safety, as well as for insurance and risk management professionals."

8.16 Measuring Consequences in Economic Terms

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À lire : [Ramachandran and Hall, 2016]

L'auteur de [Ramachandran and Hall, 2016] est un spécialiste dans le domaine. Il a composé plusieurs articles, dont au moins un dans ASTIN.

Résumé : "In any fire risk analysis or risk-based assessment, valid measurements of the severity of the fire hazard—the consequences of fire, if it occurs—are of paramount importance. Most analyses are limited to simple outcome measures, such as numbers of deaths or injuries or direct property damage, defined as direct harm to property requiring repair or replacement."

8.17 Statistical methods in risk evaluation (fire)

Article à lire : [Ramachandran, 1980].

Résumé : "This paper is concerned with the statistical methods involved in the evaluation of fire risk in an industry.
The risk could be expressed in terms of two main components—the probability of fire starting and the probability of damage reaching various levels in a fire. The latter probability involves the concept of probability distribution of fire loss, the nature of which is discussed with reference to statistical and physical considerations. The values of the parameters of this distribution and the probability of fire starting will vary depending on factors such as sources of ignition, size of the property, and the presence or absence of sprinklers.
It is shown how results for a group of similar properties could be modified for evaluating the risk in an individual property. For this purpose, detailed particulars of the property and processes will be required. If individual figures for financial losses are available only for large fires the parameters of the probability distribution of fire loss can be estimated by applying the statistical theory of extreme values. Basic principles of this theory and its practical uses are explained. As a project for further research it is proposed that a model based on stochastic processes should be developed for predicting the spread of fire in a building. An outline of such a model is given specifying the data required for estimating and validating the parameters of the model."

8.18 Quantitative Risk Assessment in Fire Safety

Autre livre de notre ami Ramachandran : [Ramachandran and Charters, 2011].

Résumé: "Fire safety regulations in many countries require Fire Risk Assessment to be carried out for buildings such as workplaces and houses in multiple occupation. This duty is imposed on a "Responsible Person" and also on any other persons having control of buildings in compliance with the requirements specified in the regulations. Although regulations only require a qualitative assessment of fire risk, a quantitative assessment is an essential first step for performing cost-benefit analysis of alternative fire strategies to comply with the regulations and selecting the most cost-effective strategy. To facilitate this assessment, various qualitative, semi-quantitative and quantitative techniques of fire risk assessment, already developed, are critically reviewed in this book and some improvements are suggested. This book is intended to be an expanded version of Part 7: Probabilistic risk assessment, 2003, a Published Document (PD) to British Standard BS 7974: 2001 on the Application of Fire Safety Engineering Principles to the Design of Buildings. Ganapathy Ramachandran and David Charters were co-authors of PD 7974 Part 7. Quantitative Risk Assessment in Fire Safety is essential reading for consultants, academics, fire safety engineers, fire officers, building control officers and students in fire safety engineering. It also provides useful tools for fire protection economists and risk management professionals, including those involved in fire insurance underwriting.".

8.19 Economics of fire: exploring fire incident data for a design tool methodology

Thèse de doctorat : [Salter, 2013]

Voir le chapitre 5 pour une analyse de données liées au péril incendie.

Résumé: "Fires within the built environment are a fact of life and through design and the application of the building regulations and design codes, the risk of fire to the building occupants can be minimised. However, the building regulations within the UK do not deal with property protection and focus solely on the safety of the building occupants. This research details the statistical analysis of the UK Fire and Rescue Service and the Fire Protection Association s fire incident databases to create a loss model framework, allowing the designers of a buildings fire safety systems to conduct a cost benefit analysis on installing additional fire protection solely for property protection. It finds that statistical analysis of the FDR 1 incident database highlights the data collection methods of the Fire and Rescue Service ideally need to be changed to allow further risk analysis on the UK building stock, that the statistics highlight that the incidents affecting the size of a fire are the time from ignition to discovery and the presence of dangerous materials, that sprinkler activations may not be as high as made out by sprinkler groups and that the activation of an alarm system gives a smaller size fire. The original contribution to knowledge that this PhD makes is to analyse the FDR 1 database to try and create a loss model, using data from both the Fire Protection Association and the Fire and Rescue Service."

Note : je crois que le superviseur de l'auteur est notre ami Ramachandran.

8.20 Générateur de scénarios d'incendie (CUrisk)

Le contenu de cette sous-section provient du rapport [Cossette et al., 2018].

Important :

- Christian Dagenais connaît l'existence de ce générateur (rencontre en mai 2021).
- Selon lui, nous ne pourrons pas avoir accès au générateur.

Il existe des générateurs de scénarios d'incendie qui sont basés sur une large et exhaustive appréhension du comportement du feu. À titre d'exemple, Carleton University a élaboré un logiciel générateur de scénarios, basé sur plusieurs sous-modèles : propagation du feu, croissance du feu, mouvement de la fumée, réponse des occupants, analyse du risque vie et analyse des dégâts occasionnés au bâtiment.

Dans les études de cas [Zhang et al., 2015b] et [Zhang et al., 2015a], CUrisk a permis de générer plusieurs scénarios qui sont des combinaisons des caractéristiques du bâtiment, à savoir les informations concernant les murs, les planchers, les portes et les fenêtres. Des informations concernant la présence ou non des gicleurs et le temps de réponse des pompiers peuvent aussi être pris en considération. Chaque scénario est initié par le choix du design de l'incendie (endroit d'initiation, heure d'initiation, etc.), puis le sous-modèle de croissance du feu permet de prédire les conditions de la propagation du feu dans les autres compartiments. Ensuite, les sous-modèles de mouvement de la fumée et de propagation du feu servent à calculer la probabilité de propagation du feu vers les autres compartiments. Les informations relatives au bâtiment sont ensuite introduites dans les autres sous-modèles qui nous informent sur le risque de perte humaine et les coûts occasionnés par le sinistre au bâtiment.

Ce générateur de scénarios pourrait être utilisé par les assureurs pour remédier, dans le cadre de la tarification en assurance des chantiers de construction des bâtiments en CLT, au problème de manque de données. Il est vraisemblable que ce modèle ne capte pas toute l'information présente dans un vrai incendie, mais plusieurs sous-modèles utilisés ont été testés et validés avec des données réelles disponibles dans la littérature comme, par exemple, les sous-modèles de mouvement de la fumée et de propagation du feu validés selon [Zhang and Hadjisophocleous, 2012]. Ceci dit, d'après [Xin and Huang, 2013], les pertes humaines estimées par CUrisk ont été comparées aux données réelles d'incendie en Ontario et aucun écart notable n'a été observé.

En faisant usage de CUrisk ou d'un autre générateur de scénarios semblable à celui-ci, et en s'adaptant au contexte de construction au Québec, les promoteurs et les chercheurs en génie du bois pourraient produire des tests quantifiant les pertes financières occasionnées au bâtiment en plus des tests assurant juste le respect des normes du code du bâtiment. Ce contraste de perspective est dû à la fonction objective qui n'est pas la même pour les assureurs (perspective de pertes financières) que pour la régie du bâtiment (perspective de pertes humaines).

9 Bois massif, péril incendie et assurabilité

9.1 Contexte

On indique les travaux menés qui examinent/discutent des trois aspects suivants: bois massif, péril incendie et assurabilité.

Structure de la section:

- Le titre de la sous-section est le titre de l'article (ou du document).
- On a reproduit le résumé et fait de brefs commentaires.

Note : Je n'ai pas eu le temps de mettre tous les articles.

9.2 A Case Study Comparing the Fire Risk in a Building of Non-combustible Frame and a Timber Frame Building

Document récent : [Karlsson et al., 2020]

Résumé : "Authorities and industry found that it was necessary to develop a new fire risk assessment technique to verify that fire safety can be as high in timber-frame buildings as in other types of buildings, given that the right construction methods be used. Nordic Wood therefore initiated work that led to the development of FRIM-MAB, a Fire Risk Index Method for Multi-storey Apartment Buildings. The method has been described in several reports and papers and was evaluated against a much more elaborate Quantitative Risk Analysis (QRA) method. Both the index method and the quantitative risk analysis were used to rank four different buildings with respect to fire risk and the ranking was identical. The method was then further tested, where 20 timber frame buildings in four Nordic countries were analysed. This work has recently been taken further by comparing the fire risk in a building of a non-combustible frame in 6 storeys and a similar timber frame building. This paper reports on that comparison."

9.3 Overview of North American CLT fire testing and code adoption

Document récent : [Zelinka et al., 2020]

Résumé : "Cross laminated timber (CLT) is becoming more widely available in North America. However, it has not yet achieved widespread use in construction in the United States because provisions for CLT have only recently been added to model building codes. For example, CLT was recognized for the first time in the 2015 International Building Code (IBC), and the 2021 IBC will allow wood buildings made of CLT and other types of mass timber to be constructed up to 18 stories high. The changes to the 2021 IBC were implemented after several years of work from an ICC Ad-Hoc committee on tall wood buildings including fire testing supervised by the US Forest Service, Forest Products Laboratory. The fire tests involved five compartment fire test scenarios on a two-story building and specifically examined occupant egress and firefighter safety in corridors near the compartments. In addition to the fire tests performed by the Forest Products Laboratory, more large-scale fire tests were performed for the revision of the PRG-320 standard; the product standard for CLT in North America. These tests examined the heat resistance of adhesives used in CLT. This paper highlights the important changes to the IBC and the PRG-320 standard as well as summarizes the tests used to validate these changes."

9.4 Chubb - CLT and Builder's Risk 2017

Auteur : Erik G. Olsen, CSP, CFPS

- Executive Property Specialist, Chubb Insurance
- Diapos à "IMUA 2017 Annual Meeting"

Important : Dans cet exposé, toutes les "critiques" à l'égard du CLT sont mentionnées

Éléments soulevés par le conférencier Erik G. Olsen :

- Builders' Risk Nuances : Fire ; Water Damage (especially roofs) ; Material Replacement
- Construction Class from a Builder's Risk Perspective : How will it burn during construction? Exposed structural? Any compartmentalization? Details on encapsulation? Any functional fire protection? Exposed Connectors?
- Critical Risk Factors... During Construction
  - Multi-story CLT type projects and large Glulam (long span) structures may have more of an erection-collapse exposure compared to load bearing MNC type projects
  - Raised floors and drop ceilings accommodate most systems
  - Moisture protection considerations (tent structures). Taller Buildings = more wind and rain.
  - Are structural wood exposed or inside bldg envelope? Weathering of wood during construction.
  - Water damage exposure is elevated. Avoiding Moisture during Construction.
  - Any ventilation systems to address moisture?
  - Avoiding staining during construction is unrealistic
  - Apply final finishes at the end of construction
- Material Replacement Considerations
  - Aesthetic and the potential structural load bearing issues and material replacement associated with the interim BR fire exposure.
  - If CLT or Glulam member is exposed to fire during project, what are the options as the project owner?
  - Future heat performance of adhesives and structural load bearing capacity once damaged?
  - As a "new" building owner, not sure I care whether a CLT or Glulam member is "structurally sound" after if it has been exposed to fire, I will probably want a "new" CLT or Glulam member.
- Post Loss Considerations
  - No guarantee supporting structure remains safe after fire even with restoration
  - Combustible insulation use and reality of fire fighting challenges (inside wooden walls etc.) when installed over wood.
  - Upon a pipe burst or leak, wood generally does not respond well. Mold and rot.
  - Loss history for all types and dimensions of wooden buildings show increased loss potential closer to 100% MFL estimates.

Summary (de l'exposé) :

- Quick Summary of Advantages

  - Reduced effect on the environment – i.e. CO2 emission during concrete manufacturing process.
  - Less energy consumption compared with concrete and steel manufacturing.
  - Much less time to construct building – 10 weeks for Brock Commons Tower structure – not including interior finishings. This is about 4 months faster than typical structure of this size.
  - Green product - natural, sustainable, lightweight.
  - Aesthetically pleasing – for interior this will depend upon the percentage of allowable exposure - Will depend on panel thickness chosen.
  - Good seismic features – flexibility and connections. Outstanding structural properties
  - For Fire Safety during construction– much less congestion and fire loading, no hot work, very clean site. NOTE: prefabricated panels manufactured off site.
  - Approximately 90% less construction traffic (trucks delivering materials) and requires 75 percent fewer workers on the active deck.

- Quick Summary Disadvantages
  - Although 2 hour fire ratings being achieved and very slow rate of char, this is still a combustible product (will continue to burn –self sustaining but temperatures continued to decline under freeburn test).
  - May still be slightly more costly than concrete/steel. However, must take into consideration environmental impact, reduced construction, time, etc. Costs should be coming down.
  - Mass Timber over 6 stories currently designated as "Alternate Solution" in the model building codes which must be accepted by the AHJ, involving numerous reviews, overdesigning, red tape, etc. to convince AHJ to accept project.
  - Water!
  - One CLT fire to date during COC – GSK lab in England (2014) – reportedly electric fire and unusual high plastic combustible loading in vicinity of fire origin. Rebuilt to same criteria – not a deterrent.
  - Industry unfamiliarity- well established supply chains often not in place, engineers/architects sometimes less aware of the possibilities of designing with wood – slowly changing.
  - Insurance industry unfamiliarity – many underwriters unaware of this construction – treated as frame.

Source : IMUA 2017 Annual Meeting Presentations

- Founded in 1930, Inland Marine Underwriters Association (IMUA) is the national association for the commercial inland marine insurance industry in the US. With members representing over 90 percent of inland marine premium writings, the Association provides its members with comprehensive training and educational programs, including research papers, news articles, industry analysis, seminars, webinars, and the impact of legislative and regulatory issues.
- Site : www.imua.org

9.5 Perception du bois massif par ISO

Une excellente introduction à la compréhension du risque liée à la construction en bois massif est fournie dans le document suivant :

- Source : [Kahn, 2020]
- Auteur : Doug Kahn. Il travaille pour **ISO** (= *Insurance Service Office*).
- Overview du document : One of the primary goals of underwriting for any property insurance policy is determining the risk of fire. And one of the main considerations in making that determination is assigning the proper construction class. What are the materials? What percentage of the structure consists of each kind of material? How much damage will the building sustain when exposed to fire? Properly identifying the construction class can help the underwriter rate the risk more accurately.
- Mass Timber : A type of engineered wood made by affixing many pieces of wood veneers, flakes, or dimension lumber to form larger, stronger pieces—doesn't fit easily into the insurance industry's existing construction classes. It challenges the assumption that combustible materials aren't suitable for tall buildings. Economic and environmental forces are driving mass timber into mainstream use, so it's important that insurers understand its advantages and risks.

NOTE : j'ai essayé à plusieurs reprises de le contacter par courriel. Je n'ai pas reçu de retour de sa part.

9.6 Projet de la CIRCERB 2017

Face à ces divergences, la Chaire industrielle de recherche sur la construction écoresponsable en bois (CIRCERB) de l'Université Laval a jugé nécessaire de réaliser une étude portant sur l'adéquation de la prime attribuée aux structures en CLT ainsi que sur la méthode actuarielle sur laquelle est basée son évaluation. Un projet de recherche a donc été lancé à dans le but d'étudier le processus de tarification des polices d'assurance construction pour les structures en CLT. Réalisé à l'École d'Actuariat de l'Université Laval, par Mohammed-Amine Ennajeh et Anas Koubaa sous la supervision d'Étienne Marceau et Hélène Cossette, le projet avait pour objectifs de :

- Expliciter les éléments influençant la prime d'assurance en construction au Canada ;
- Tarifer les risques associés aux périls inhérents à un chantier de construction en bois lamellé-croisé ;
- Déterminer les facteurs responsables de la surévaluation de la prime proposée par les assureurs.

Dans leur rapport [Cossette et al., 2018] pour ce projet, les auteurs ...
Enquête auprès d'actuaires, de souscripteurs et d'experts du secteur canadien de l'assurance ([Cossette et al., 2018])

- Deux principaux obstacles pour l'assurabilité des chantiers de construction pour les produits CLT sont la taille du marché et le manque de données sur son sinistre
- En l'absence de données sur les sinistres, les actuaires et les souscripteurs ont différentes approches en fonction de leur appétit pour le risque et selon le plan de souscription :
  - classer le projet de construction CLT selon l'une des 6 classes de construction ISO existantes
  - le choix de la classe dépend de l'appréciation des souscripteurs
  - le choix le plus défavorable est la classe de construction 1
  - le choix le plus favorable est la classe de construction 3
  - voir aussi [Teasel, 2020]

9.7 Actuariat et bois massif : enjeux importants (JP Boucher)

D'après [Cossette et al., 2018], il n'y a pas de contribution actuarielle académique sur les sujets suivant :

- Assurance chantier / assurance construction
- Risque incendie vs bois massif
- Niet

Selon JP Boucher, les deux enjeux importants sont les suivants :

- Loi de fréquence ⇒ exposition
- Loi de la sévérité ⇒ sinistres avec des montants élevés

Modélisation de la distribution de férquence:

- Il manque de données.
- L'exposition est cruciale pour le calcul de prime

Modélisation de la distribution de sévérité:

- On a des données
- Il faut jouer avec les données
- On y travaille

9.8 Joint research project by NFPA & Property Insurance Research Group

In 2014, the US National Fire Protection Association (NFPA) and the Property Insurance Research Group (PIRG) launched the following research project :

- Name: Fire Safety Challenges of Tall Wood Buildings
- Main objective: analyze and quantify the fire risk for CLT structures vis-à-vis other structures used in high-rise buildings

Sponsors :

1. American Wood Council (AWC)
2. US Department of Agriculture, Forest Service
3. National Research Council (NRC) of Canada
4. Property Insurance Research Group (PIRG):
    - AIG (AIG =American International Group, Inc.)
    - CNA Insurance (CNA = Continental National American Group)
    - FM Global (FM = Factory Mutual)
    - Liberty Mutual Insurance
    - Tokio Marine America
    - Travelers Insurance
    - Verisk (ISO)
    - XL Group (Axa XL since September 2018)
    - Zurich Insurance Group

Property Insurance Research Group (the "PIRG"):

- Formed in 2010 to support the mission and activities of the Research Foundation of NFPA
- Provide a forum for members of the property insurance industry to discuss industry-relevant fire protection issues and identify related research needs that could be met through research projects conducted by the Foundation
- Provide a continuing mechanism to recommend research projects to the Foundation and to provide, through a fund consisting of member contributions (the "PIRG Fund"), financial support for PIRG-recommended projects undertaken by the Foundation.

Completed reports :

1. Fire Safety Challenges of Tall Wood Buildings Phase 1: [Gerard et al., 2013]
2. Fire Safety Challenges of Tall Wood Buildings Phase 2 Task 1 Literature Review: [Brandon and Östman, 2016]
3. Fire Safety Challenges of Tall Wood Buildings Phase 2 Tasks 2-3 Development and Implementation of CLT Compartment Fire Tests : [Su et al., 2018]
4. Fire Safety Challenges of Tall Wood Buildings Phase 2 Tasks 4 Engineering Methods : [Brandon, 2018]

5. Fire Safety Challenges of Tall Wood Buildings Phase 2 Tasks 5 Experimental Study of Delamination of Cross Laminated Timber (CLT) in Fire : [Brandon and Dagenais, 2018]

Main goal of Phase 2 : "To quantify the contribution of CLT building elements (wall and/or floor-ceiling assemblies) in compartment fires and evaluate the relative performance of CLT systems compared to other buildings systems commonly used in tall buildings."

This involvement of the PIRG in this project demonstrates the interest of major insurers and reinsurers to better identify and understand the risk associated with CLT structures for the construction of high-rise buildings.

Given that the CLT has robust characteristics in terms of behavior and response to the various perils, insurers have deemed it necessary to launch this study in order to better quantify and price the risk inherent in CLT while waiting to observe its true loss experience.

10 Travaux et données de Len Garis

[...]

11 Intégrer l'avis d'experts

[...]

12 Fire Frequency

L'exposition est cruciale pour la modélisation des dommages liés au péril incendie.

Nous regroupons les articles liés à la survenance des incendies.

12.1 Assessing fire frequency and structural fire behaviour of England statistics

À lire : [Manes and Rush, 2021].

Résumé : "Contemporary structural fire statistics are fundamental in engineering design practice to evaluate likelihood and consequence of fire for different property types, and to investigate how different safety measures impact fire spread. British Standard PD 7974-7:2003 has recently been updated using USA fire statistics; this paper compares PD 7974-7:2003 to current England statistics (named UK statistics) using one public and one Home Office dataset. PD 7974-7:2003 overestimates fire frequency with values up to 5 times greater than the ones found in UK and USA. When fire frequency is plotted against total floor space, for different property types, power laws with positive or negative exponent and polynomial functions provide better approximations of the data than the current codes. Average area damage from PD 7974-7:2003 has been compared to fire and total damage from UK datasets where fire size is usually well confined to room of origin at 20% of fires based on the publicly available dataset. When fires exceeding specific areas of damage are considered, PD 7974-7:2003 usually overestimates fire damage and underestimates total damage, with more damage evident when sprinklers are absent compared to when they are present.".

12.2 A fire risk simulation system for multi-purpose building based fire statistics

À lire : [Chi et al., 2011].

Résumé : "Statistical data over the past 24 years detailing the number of fires and building floor areas published by the Taiwan government was employed to determine the fire probability, frequency, and cycle for each building category. By applying a matrix calculation, the fire probability, frequency, cycle, and risk ratio for each functional area within a multi-purpose building were obtained. With assistance from the Taiwan government, the fire case investigation and statistical data for building fires were established. By adopting the risk ratio concept, the weight values for 20 fire safety assessment criteria and 4 fire safety strategies for a multi-purpose building were acquired to indicate the possible causes of fires and the quantitative extent of fire influence."

12.3 Fire loss in the United States during 2016

À lire : [Haynes, 2016].

Résumé : "United States fire departments responded to an estimated 1,342,000 fires in 2016. These fires resulted in 3,390 civilian fire fatalities, 14,650 civilian fire injuries and an estimated 10.6 billion US dollars in direct property loss. There was a civilian fire death every 2 hours and 35 minutes and a civilian fire injury every 35 minutes 54 seconds in 2016. Home fires caused 2,735, or 81 percent, of the civilian fire deaths. Fires accounted for four percent of the 35,320,000 total calls. Seven percent of the calls were false alarms; 64 percent of the calls were for aid such as EMS."

13 Conclusion

[...]

Acknowledgment

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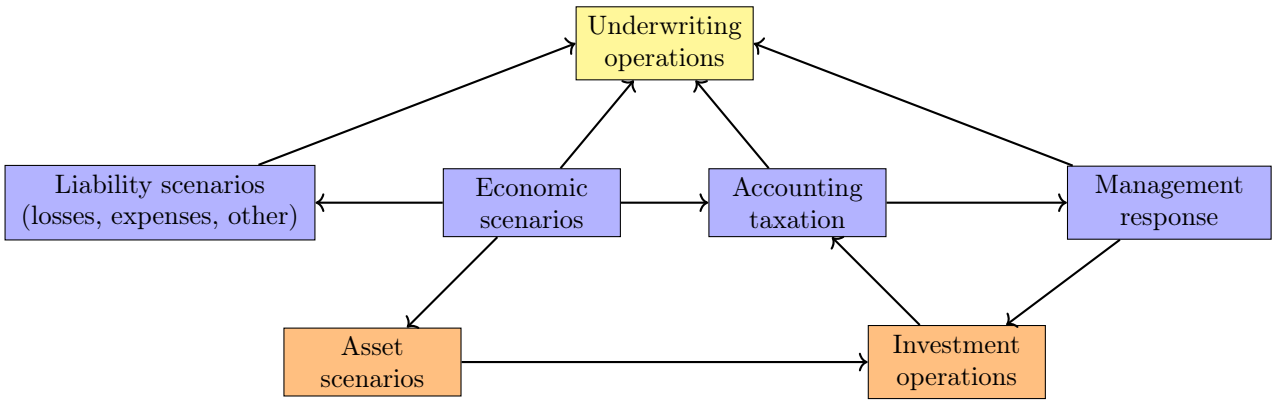
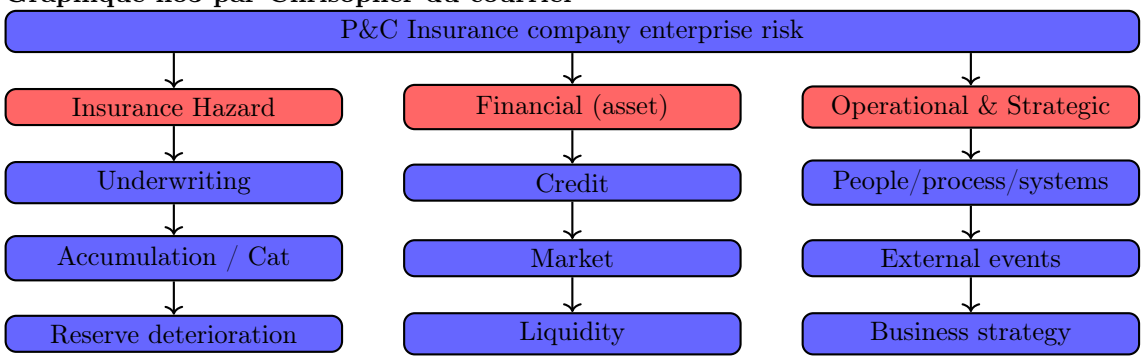
A Deux graphiques de Christopher

Graphique no2 par Christopher du courriel



Graphique no3 par Chrisopher du courriel



Taxonomie du risque tiré de **Brehm, P.; Gluck, S.; Kreps, R.; Major, J.; Mango, D.; Shaw, R.; Venter, G.; White, S.; and Witcraft, S., Guy Carpenter, "Enterprise Risk Analysis for Property & Liability Insurance Companies,"**